# 2014 South Delta Chinook Salmon Survival Study

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3 July 2018

## Table of Contents

# Introduction

This study focused on estimating juvenile Chinook Salmon *Oncorhynchus tshawytscha* survival through the San Joaquin River and Delta (and routes contained within) and in combination with other years of data, relating it to water temperature, river flow, and Central Valley Project and State Water Project exports with the physical barrier at the head of Old River. Although three releases of juvenile salmon were made between April 15 and May 30, 2014, the first release suffered from premature battery failure associated with a software bug in the tag. The software bug in the tag was fixed for the second and third releases prior to release, but was not identified as a problem prior to the first release. Disease was also encountered in fish at Merced River Fish Hatchery, so the fish source and tagging location of this juvenile salmon study were changed and moved to the Mokelumne River Hatchery (MKRH). Each of three releases consisted of between 629 and 646 fish tagged over a four day period and released over a five day period. In addition, tags were purchased and used to assess tag life. The installation, operation, maintenance, and removal of the acoustic receiver array in the lower San Joaquin River and Delta and downloading of the data was conducted by U.S. Geological Survey (Sacramento office) with U. S. Bureau of Reclamation funding as part of the Six-year Steelhead Study. California Department of Water Resources contributed to the project by funding the tags for the last release to assist them and the National Marine Fisheries Service (NMFS) in determining how predator removal might influence salmon smolt survival (Hayes et al. 2017). Staff from University of Washington conducted the data analyses and the writing of much of this report.

## Project Goals and Objectives

The main goal of this project was to estimate juvenile salmon survival through the Delta in April and May of 2014 and compare it between releases and with prior years to identify factors influencing survival as the fish migrate downstream. Mortality is hypothesized to be related to operational changes in hydrology (i.e. San Joaquin inflow, Central Valley Project and State Water Project exports, and the presence or absence of the head of Old River barrier) as well as water temperature as the juvenile salmon smolts out-migrate from the San Joaquin River basin through the Delta.

Specifically the six objectives of the project are:

a) Determine survival of tagged salmon smolts from Durham Ferry and Mossdale through the Delta to Jersey Point and Chipps Island.

b) Identify the proportion of fish entering Turner Cut and Old River.

c) Determine the survival for fish taking different pathways to Chipps Island (e.g., Old River route versus the San Joaquin River route).

d) Identify reach-specific mortality of tagged fish in 2014.

e) Compare survival across releases and between years

f) In conjunction with past results, assess the role and influence of water temperature, flow, exports, and the presence or absence of a barrier at the head of Old River on survival in these migratory pathways.

## Background

Chinook Salmon escapement in the San Joaquin basin tributaries has fluctuated dramatically for over 50 years. These fluctuations in adult abundance appear to be related to river flow during the spring outmigration period of the juveniles, with higher numbers of adults returning to the basin 2.5 years after spring periods with higher flows (SJRGA 2007). Survival through the south Delta to Jersey Point has been measured in the spring as part of the Vernalis Adaptive Management Plan (VAMP) and in studies pre-dating the VAMP. Coded wire tags (CWT) were used to monitor survival between 1994 and 2006. After 2006, survival through the Delta to Chipps Island was estimated for the VAMP, and years thereafter, using acoustic tags (i.e., 2008, 2010, 2011, 2012, and 2013). The VAMP study ended in 2011. Survival estimates in 2008 were potentially biased due to premature battery failure. The study in 2014 was the sixth year of estimating survival through the Delta using acoustic tags. The first release in 2014 also suffered from premature battery failure and survival estimates for that group are likely biased.

River flow has varied considerably over these six years; 2010 and 2011 were above normal and wet water year types, respectively, and 2008, 2012, and 2013 were dry/critical water year types. Conditions in 2014 were also very dry (i.e., critical water year type) and it was the third consecutive year of drought. A barrier is sometimes placed at the head of Old River (HOR), but the presence and type of barrier has also varied during the studies. There was no HOR barrier (HORB) in 2008, 2011, or 2013. There was a physical barrier in place during salmon survival studies in 2012 and 2014, and a non-physical barrier (bio-acoustic fish fence) was tested in 2010 (SJRGA 2011). The physical HORB was also in place in many of the years during the earlier CWT studies (1994, 1997, 2000–2004) when flows allowed it. The physical HORB can now only be installed when flows are less than 5,000 cfs and operated when flows are less than 7,000 cfs at Vernalis. In earlier years (e.g., 1992), the flow limits for installation and operation of the physical HORB were lower.

The use of acoustic tags allows survival to be measured between routes and in specific reaches of the Delta to identify areas of high mortality. One complication with the use of acoustic tags is the quantification of predation on tagged fish that pass by receivers after they have been consumed. We have addressed this concern since 2009 by using a predator filter to identify detections of tags deemed likely to be in a predator, and then analyzing the data first using all acoustic tag detections and then again with only those detections classified as still in salmon smolts. The difference in survival estimates using the two methods allows us to evaluate the potential bias associated with this predation complication.

Surival estimates from juvenile Chinook Salmon from Durham Ferry and Mossdale to Jersey Point and Chipps Island using acoustic tags were completed in 2011, 2012, and 2013, making 2014 the fourth year for survival estimates using acoustic tags in the south Delta. Survival was also measured from Durham Ferry and Mossdale to Chipps Island in 2010, but not to Jersey Point. Survival to Jersey Point and Chipps Island was measured in 2008, but estimates were potentially biased due to premature battery failure and no predator filter. Data gathered from the second and third releases in 2014 were added to those gathered in previous years and used to develop models for assessing the effects of flow, water temperature, exports, and a physical barrier at the HOR. Only two valid estimates of survival were available in 2014 because the first release group used tags that suffered from premature battery failure.

Fish from Merced River Hatchery have been used for south Delta survival studies since 1994. Merced River Hatchery fish often have Proliferative Kidney Disease (PKD), especially in dry years (SJRGA 2013). Infection with *Tetracapsuloides bryosalmonae* (a myxosporean parasite) causes PKD (Okamura and Wood 2002). PKD is a progressive disease at water temperatures greater than 15° C (Ferguson 1981; Hedrick et al. 1986). Clinical PKD occurs more quickly as water temperatures increase from 12–18° C, whereas it does not multiply at 9° C (Clifton-Hadley et al. 1986). *T. bryosalmonae* infection can reduce a fish's performance due to associated kidney dysfunction and anemia. However, infection with the parasite does not necessarily kill the fish. *T. bryosalmonae* has been reported at Merced River Hatchery since the 1980s (Hedrick et al. 1986) and in California since at least 1966 (Hedrick et al. 1985).

While differential kidney inflammation due to PKD between upstream release groups and Jersey Point release groups could have biased survival estimates derived from CWTs, there was no evidence there was differential infection rates within paired releases (SJRGA 2013). However, PKD could affect the survival estimates derived from acoustic-tagged fish used in these studies because the acoustic tag methodology does not pair upstream and downstream release groups for estimating survival. Because fish from MKFH typically do not have PKD, using study fish from the MKRH in 2014 provided an opportunity to determine if the low survival observed in the south Delta in recent years using Merced River Hatchery fish was due primarily to the fish being infected with PKD.

## Conceptual Model and Hypotheses

As with the north Delta (Perry et al. 2010), survival through the south Delta is a combination of survival in each route and the proportion of the population entering each route. In the north Delta, the probability of route selection is a function flow, water velocity and the proportion of total outflow entering each river channel (Perry 2010: Ch. 6). In the south Delta, there is the added factor of whether there is a barrier installed at the river junction (SJRGA 2013). Tagged salmon that stay in the San Joaquin River at the Old River junction can move into the Old River route via Turner and Columbia Cuts and at downstream junctions. For instance, in 2011, approximately 21% of the tagged fish on the San Joaquin River that approached the Turner Cut junction entered Turner Cut (SJRGA 2013). Measuring survival and route selection as the tagged fish move downstream is one of the first steps for identifying causes of the high mortality in the Delta for smolts originating from the San Joaquin River basin.

Survival in the south Delta is hypothesized to be related to San Joaquin River flow and water temperature. Exports serve to reduce flows downstream of the export facilities and cause direct mortality due to entrainment at the water facilities. To meet water demands at the Central Valley Project (CVP) and for irrigation districts on the San Joaquin tributaries, the dam on the mainstem San Joaquin River and those on the San Joaquin River tributaries (Stanislaus, Tuolumne and Merced rivers) serve to hold back the spring flows originating from snowmelt, reduce downstream flows in the rivers in the spring, summer, and fall, and likely increase water temperatures during the spring (Brown and Bauer 2009). Because dams greatly dampen the seasonal interannual streamflow variability of rivers and homogenize the flow regimes, dams serve to create conditions that favor non-native species at the expense of native species (Poff et al. 2007; Brown and Bauer 2009).

Agricultural wastewater drains into the San Joaquin River (Nichols et al. 1986), while suspended sediment into the Delta has declined and water clarity has increased (Wright and Schoellhamer 2004 and Hestir 2010, cited by Ustin 2015). These changes in the San Joaquin River and Delta have made the Delta ecosystem vulnerable to a host of invasive species, including two freshwater plant species that flourish in high-nutrient conditions: the floating species Water Hyacinth *Eichhornia crassipes* and the submerged species Brazilian Waterweed *Egeria densa* (Ustin 2015). Once well-established, these invasive plant species are resistant to change due to positive feedback loops (Scheffer and van Nes 2007, cited by Ustin 2015), resulting in conditions that increase the survival and persistence of submerged aquatic vegetation (Santos et al. 2012, cited by Ustin 2015).

During the spring, water temperatures in the San Joaquin River at Mossdale are associated with flow, with lower flows resulting in higher water temperatures (Stringfellow 2012; SJRGA 2013: Figures 6–23). Water temperature is a major limiting factor for juvenile Chinook Salmon in the Central Valley (Moyle 2002). Increased water temperature may increase the incidence and severity of PKD (Ferguson 1981) at Merced River Hatchery (Hedrick et al. 1986) and in the San Joaquin River tributaries (Nichols and Foott 2002). Predation rates during the time the fish are migrating through the Delta are also likely increased at higher water temperatures due to higher bioenergetic demands (Hartman and Brandt 1995) of predatory fish, particularly striped bass and largemouth bass, and a reduction in swimming performance (Lehman et al. 2017) of the juvenile salmon prey. The combination of clearer water with more submerged aquatic vegetation and higher water temperatures may result in a greater number of warm water predators and a higher predation rate from those predators that combine to result in higher predation risk for open water species (Ferrari et al. 2013) such as juvenile salmon. The reduction in swimming performance of juvenile salmon as prey would increase the success of those predators.

Our hypothesis is that survival in each reach of the south Delta is a function of time in each reach (a function of distance and water movement and velocity) and water temperature. Increasing inflow and decreasing reverse flows is hypothesized to increase the migration rate of individual fish through the riverine parts of the Delta and thus decrease the time fish are exposed to mortality factors such as predation, high water temperatures, and toxins; increased inflow is also hypothesized to reduce the effect of toxins via dilution, and lower the predation risk by lowering water temperature and increasing turbidity. These hypotheses are based on evidence that flow increases survival in some reaches of the rivers (Sacramento River, Steamboat and Sutter sloughs, and from Durham Ferry to Mossdale) (Perry 2010; SJRGA 2013). There is also some information that suggests that predation is lower at higher flows (Bowen and Bark 2012; CDWR 2015).

Extremely high inflow may also push the tidal prism downstream such that fewer fish are diverted into the interior Delta at Turner Cut and Columbia Cut as has been shown with Georgiana Slough (Perry 2010) and at Old River (SJRGA 2013). However, in most years, river flows are generally low in the San Joaquin River, and in some dry years, flows actually reverse in the San Joaquin River and go upstream into Old River to supply the pumping facilities with water. These low flows and reverse flows likely increase the travel time of juvenile salmon down the mainstem San Joaquin River and contribute to the high mortality observed.

Once fish enter the interior Delta or into the strongly tidally influenced San Joaquin River, residence times increase and survival decreases. The increased residence time makes juvenile salmon more prone to predation or other mortality factors because it takes them longer to migrate through these parts of the Delta. High mortality has been measured in the Stockton deepwater ship channel and between Medford Island and Jersey Point (SJRGA 2013), suggesting migration through these large bodies of slow-moving water does increase mortality. Increasing exports could increase or reduce residence times in the Delta, depending on which route the fish take. If fish are routed to the facilities through Turner and Columbia Cuts, their Delta residence times will increase compared to residence times if they were routed to the facilities more directly through upper Old River. However, whether higher exports increase or decrease survival also depends on the success of salvaging entrained fish once they arrive at the fish facilities. Direct entrainment or indirect mortality through predation at agricultural diversions and the water projects is also a factor affecting survival in the reaches where these facilities are located.

In recent months, two analyses have confirmed or refuted some of the ideas in our conceptual model. Perry et al. (2018) illustrates how Sacramento River inflows are key to survival and entrainment routing in the Sacramento River Delta due to the relationships between flow and survival in reaches that transition between unidirectional and bidirectional flow from tidal influences and the relationship between route selection and flow. At low flows, more fish are diverted into routes with lower survival (e.g., Georgiana Slough), the effect of which is compounded by the lower survival in the remaining transitional reaches due to the reduced flow in those reaches. Perry et al. (2018) also found travel time was inversely related to river inflow in all reaches. These results all support our conceptual model that increased flows decrease travel time, affect route selection probabilities, and increase survival in some reaches of the Delta, which in turn increases survival through the whole Delta. Survival was not related to travel time in the downstream tidal reaches, which suggests different mechanisms for survival in the downstream tidal reaches.

Buchanan (2017) illustrates the complex interaction between flows and survival in the south Delta. Analyses of acoustic tag study results between 2010 and 2013 suggest that survival increases with flow 1) between Mossdale and the Old River junction up to about 4,500 cfs (Buchanan 2017: Table

17 and Figure 42) and 2) from HOR to Chipps Island in both the Old River and San Joaquin routes (Buchanan 2017). The probability of staying in the San Joaquin River at the Old River junction was found to increase with increased flows in the San Joaquin near Lathrop (Buchanan 2017). In addition, survival between Mossdale and the Old River junction decreased at higher water temperatures (Buchanan 2017). These results seem consistent with our conceptual model. However, most of the variability in survival between HOR and Chipps Island was related to the 3-d Root Mean Square (RMS) of Old River flow at Bacon Island, with a significant positive effect. The RMS is a measure of the amount of water passing a fixed point, regardless of flow direction. These results are more difficult to understand and do not appear to support our conceptual model, but instead suggest that survival to Chipps Island is strongly related to conditions in the lower reaches of the Delta.

Both the north Delta and south Delta analyses suggest high mortality in downstream (tidal) reaches of the Delta. Furthermore, Perry et al. (2018) found that at low inflows, median travel times for tidal reaches were considerably longer than for other reaches in the Sacramento River Delta. In addition, at low flows, median travel times for the interior Delta were about three times greater than those in the tidal reach of the lower Sacramento River (Perry et al. 2018).

## Study Design for 2014

Study design for the 2014 Chinook Salmon study was similar to the design of the 2012 and 2013 studies, but was updated for revised receiver locations and sample sizes. Sample sizes were increased from 480 fish per release in 2012 and 2013 to 648 fish per release in 2014, on account of the low through-Delta survival observed in 2011 (0.02), 2012 (0.03), and 2012 (0.02) (SJRGA 2013; Buchanan et al. 2015, 2016). Both 2012 and 2013 had a release group in which no tagged fish were detected at Chipps Island, indicating either very low survival, inadequate sample size, or both (Buchanan et al. 2015, 2016). Before the study in 2014, we evaluated whether to incorporate a supplemental release downstream or consider releasing fish just at night, both to increase the probability of some tagged Chinook Salmon surviving to be detected at Chipps Island and to improve survival from the release site to Mossdale. Based on the sample size analyses, a supplemental release was not expected to improve estimation of survival to Chipps Island with the HORB in place, and using a supplemental release tended to degrade the precision of the performance metric estimates (e.g., route specific survival) (Appendix A). Survival data from Durham Ferry to Mossdale in 2012 were analyzed to compare fish released at night vs day, where “night” was interpreted to begin at sunset (1945 hours) and end at sunrise (0600 hours), to determine if it would be beneficial to release fish only at night. For the first release group in 2012, the day and night groups had the same survival from Durham Ferry to Mossdale (0.625). In the second release group, the night group had significantly lower survival (0.280) from Durham Ferry to Mossdale than the day group (0.431) ($\alpha = 0.05$). Thus, neither analysis suggested a change from previous protocol. As a result of this finding, all study fish tagged in 2014, as in 2011–2013, were released at Durham Ferry, and throughout the tidal cycle to better represent natural fish migrating down the river.

The decision to release fish at Durham Ferry was based partly on historical precedent. Experimental fish have been released at Durham Ferry for VAMP since 2000 (with the exception of 2006) to estimate survival through the Delta. Releasing fish as far upstream as Durham Ferry allows fish to distribute naturally prior to reaching the junction at the head of Old River. In 2006, CWT fish were released at Mossdale instead because flow was diverted into Paradise Cut due to the unusually high flows that year (SJRGA 2007). In subsequent years with acoustic tags, it was still advisable to make releases at Durham Ferry so that the initial handling mortality in the reach between Durham Ferry and Mossdale could be removed prior to estimating survival through the Delta (i.e., from Mossdale to Jersey Point and Chipps Island).

## Update of 2010–2013 Multiyear Covariate Analysis

The multiyear analysis of survival and route selection previously completed for 2010–2013 was updated for 2014. The predictions of the existing models were assessed for the new data, and the modeling process was redone using the available data from 2014. However, because of the high incidence of tag battery failure in the first release group from 2014, the potential for updating the previous analysis was limited.

The multiyear analysis of survival and route selection for 2010–2013 included three models relating fish performance to covariates: survival from Mossdale to the receivers just downstream of the head of Old River (SJL and ORE), route selection at the head of Old River, and survival from the SJL and ORE receivers to Chipps Island (Buchanan 2017). All models were based on tagged fish that were detected at Mossdale (MOS), SJL, or ORE.

The first (i.e., mid-April) release group suffered from a high rate of premature tag failure, so no attempt was made to test or update the 2010–2013 analysis of survival using data from the first release group from 2014. The second and third release groups in 2014 (late April through mid-May) did not suffer from the same high level of premature tag failure, and so the 2010–2013 survival and route selection models were tested and updated for 2014 data using those two release groups. All three release groups were used to test and update the 2010–2013 model of route selection, which is based on only those tags that were actually detected at the SJL or ORE receivers. Under the assumption of common tag survival to those sites (i.e., common travel time), the premature tag failure in the first release group would not affect modeling results.

# Methods

## Study Fish

Approximately 3,000 fall run Chinook Salmon smolts were requested from the California Department of Fish and Wildlife on November 26, 2013, to meet the study fish needs of the 2014 Chinook Salmon study. A total of 2,619 fish were to be allocated for releases (1,944), dummy-tagged fish transported to the release site for condition assessment (225), training (300), tag effect studies (150), and disease assessment (30) at the hatchery. The remaining fish were extra and were to be used to compensate for any culling or mortality during the tagging process.

The tagging operation was set up in late March at Merced River Hatchery and tag training took place there on April 8, 9, and 10. Training surgeries revealed health issues in the 300 fish selected for training. Due to warm water conditions and the presence of Ich *Ichthyophthirius multifiliis*, fish were determined to be unsuitable for use in the tagging study. Thus the tagging operation was moved from Merced River Hatchery to the MKRH. All equipment that was in place at Merced River Hatchery was decontaminated with Ovadine, frozen for 24 h (if possible), and transported to MKRH so tagging operations could resume there the following week.

For each of the three tagging weeks, 800 salmon were sorted by size to retain fish greater than 8.3 g to ensure a maximum tag weight to body weight ratio of 5%. These fish were smaller than those used in previous years (a minimum size of 13 g and 105 mm fork length [FL] in past acoustic studies in the South Delta) because tags were smaller (approximately 0.43 g), thus fish could be tagged earlier in the season and at a smaller size while still adhering to the recommended maximum 5% tag to body weight ratio. For the sorting process, we first weighed and measured each fish and used 95 mm as an acceptable length criterion to form our stock pool. Prior to tagging for the week, fish were sorted from a raceway that contained 25% CWT salmon. No CWT fish were used in the study and the sorted fish were transferred to a fiberglass holding tank in the MKRH spawning building.

Prior to each day's tagging, 200 fish were moved from the spawning building to four 121-L (32-gal) perforated garbage cans that were placed in a raceway near the tagging trailer. Each can contained a minimum of 113 L (30 gal) of water and was perforated with 3/8-in (9.5-mm) holes, which easily met space requirements for holding fish (<15 g/L: Peven et al. 2005). These fish were then carefully individually netted into anesthesia buckets as needed for tag implantation. Food was withheld from study fish for 24 h prior to transmitter implantation.

## Tags

Tags used in 2014 were a new model (V4) from VEMCO and were smaller than those used in the past for south Delta survival studies. The VEMCO V4 acoustic tags used for this study weighed an average of 0.414 g in air (range, 0.401–0.427 g). Tags arrived at the Stockton FWO (in Lodi, CA) on March 26, April 10, and April 30, which was approximately 21 d prior to tagging to accommodate the weighing, soaking, and distribution of tags into pill boxes for tagging.

Tags were custom programmed with two coding schemes which encorporated three separate tag codes in 2014: a traditional Pulse Position Modulation (PPM) style coding (one tag code) that pulsed every 60 s (mean), along with one hybrid PPM/High Residence (HR) coding (two tag codes) every 60 s. Eight high residency IDs were superimposed and transmitted on each Hybrid transmission every 60 seconds. All data was transmitted at 180 kHz. Each tag transmitted IDs every 30 s, on average. The HR component of the coding allowed for detection in areas where collisions (i.e., many tags emitting signals at the same time to the same receiver) were anticipated.

Tags were programmed using delays of 25–35 s alternating between PPM and HR/PPM to satisfy both VR2Ws and HR Receivers. Although the presence of the HORB in 2014 meant that we did not expect many tags to be detected in Clifton Court Forebay or at the Tracy Fish Facility, tags normally accumulate in these areas, which could affect detection rates due to signal collisions; the HR receivers were designed to improve detection rates under such conditions.

## Tag Activation

Tags were weighed and then soaked in a mild saline solution for approximately 24 h prior to activation. After soaking, tags were dried and activated one day prior to tagging. The date and time of activation was noted to the nearest minute. Tags were activated using a VEMCO activator (Figure 1). Each activated tag was then placed in a specific pillbox along with the uniquely coded vial. Because the tags had no external identifiers, the codes on the vials were used to track the specifications (e.g., manufacturing serial number and tag code) of individual tags.

## Tag Life Study

An in-tank tag life study was conducted by U.S. Bureau of Reclamation to quantify the rate of tag extinction for the V4 tags used for this study. Three in-tank tag-life studies of VEMCO V4 tags were planned using 33 tags systematically selected within each release group, for a total of 99 tags. However, the group of tags from the first lot of tags (April) indicated a high rate of premature tag failure. A fourth tag life study was then added to represent supplemental tags provided as replacements throughout the study. Thus, there were four tag life studies in all. The first tag life study began April 17, 2014, and ended May 11, 2014. The second study ran from May 5 to July 12, 2014, while the third and fourth (i.e., supplemental) tag life studies both ran from May 30 to July 29, 2014. Tags were monitored in tanks using fixed-site hydrophones and receivers to continuously monitor the tags in the tanks. There were only 25 tags/tank to minimize tag collisions. Data files were processed at the end of the tag life studies to determine whether tags were still functioning. The date and time of the last transmission was recorded for each tag and was used in conjunction with the time of activation to determine the active life of each tag. The tag life studies were conducted at the Tracy Fish Collection Facility and water temperatures in the tanks were similar to those in the Delta.

## Surgeon Training

Surgeon training occurred April 8, 9, and 10 at Merced River Hatchery one week prior to the initiation of Chinook Salmon tagging for the study at MKRH. Equipment and tagging stations were set up at the Merced River Hatchery on April 3 and 4, and then moved to the MKRH after training at Merced River Hatchery and before tagging for the study began at MRKH the following week. Four surgeons were trained, but only three were used. Training followed the same general process as in previous years.

## Fish Sorting

### First tagging week (4/15/2014 - 4/18/2014)

Because tagging commenced at MKRH on such short notice, we sorted fish the morning of the first day of tagging. Fish were sorted from raceway A, a production raceway, that contained 25% CWT juvenile salmon. No CWT fish were used for tagging. A scale and measuring board were used for the first approximately 20 fish to get a visual estimate for the size of fish we were targeting. The remaining fish were “eye-balled” as to what size we needed. To be consistent, we proceeded with the same method for the remaining three days of tagging for the week.

### Second tagging week (4/29/2014 - 5/2/2014)

During the first week of tagging we were able to secure two 2,271-L (600-gal) fiberglass tanks in the spawning building at MKRH. Each tank was divided in half; we used three of the sections for tag retention studies and the last section as a holding tank for study fish in the second and third weeks of tagging that were sorted to size. At the end of each tagging day during the first week of tagging, fish were again sorted from raceway A and put in the fiberglass tank where they were on feed until the second week of tagging. Each morning of the second week of tagging, approximately 200 fish were transferred by bucket from this holding tank to the holding cans in the raceway adjacent to the tagging trailer.

### Third tagging week (5/14/2014 - 5/17/2014)

The week preceding the third week of tagging, tagging personnel went to the hatchery and sorted approximately 800 fish from tank 47 in the spawning building to the fiberglass holding tank. Again, these fish were put on feed until the third week of tagging. Each morning of the third week of tagging, approximately 200 fish were transferred by bucket to the holding cans in the raceway adjacent to the tagging trailer.

## Fish Tagging

Study fish (N = 1,918) were tagged over three tagging weeks: 4/15/2014–4/18/2014 (N = 643), 4/29/2014–5/2/2014 (N = 646), 5/14/2014–5/17/2014 (N = 629). An additional 75 fish were dummy-tagged each week to assess health after being held for 48 h in the river at the release location.

A total of 10 people were required for tagging, including three surgeons, three assistants, two runners, one person for tag validation, and one tagging coordinator. One surgeon was provided by NMFS as part of the California Department of Water Resources predator control study; the other two were USFWS employees (Figure 2). In addition, two truck drivers assisted during tagging by loading fish into the transport tank.

Tagging occurred on Tuesday, Wednesday, Thursday, and Friday of the first two tagging sessions, with a morning (0830–1130 hours) and afternoon (1200–1500 hours) shift. For the last tagging session, tagging occurred on Wednesday, Thursday, Friday, and Saturday with the same shifts (Table 1). During each tagging session, fish were surgically implanted with V4 tags following procedures based on a standard operating procedure (SOP) developed by the Columbia River Research Lab of the United States Geological Survey (CRRL-USGS) (Liedtke et al. 2012) and the 2014 Steelhead SOP (Appendix B). The SOP directed all aspects of the tagging operation, and at least one quality assurance check was made during each tagging session to ensure compliance with the SOP guidance. Prior to transmitter implantation, fish were anesthetized in 39.5 mg/L AQUI-S 20E until they lost equilibrium. Fish were removed from anesthesia, measured (FL to nearest millimeter), and weighed (to nearest 0.1 gram).

Average fish weight was 11.1 g (range, 8.3–20.2 g). Average FL was 98 mm (range, 80–119 mm). Average surgery times were 2:18 (mm:ss; range, 1:35–4:11). Once tags were implanted, fish were placed into 19-L (5-gal) non-perforated buckets filled with 10 L of water with high dissolved oxygen concentrations (130–150%). Fish were in these buckets with high oxygen levels for 10 min to recover from anesthesia effects. Buckets contained either one or two fish, depending on tagging order, to assist with tag validation. These buckets were given similar identification numbers (e.g., 1A, containing two fish, and 1B, containing one fish) to assist in their combination after tag validation.

## Tag Validation

After tagging, tag codes were validated using one of two VR100 receivers and its associated 180 kHz hydrophone (Figure 3). The hydrophones were placed gently in each recovery bucket and held there until the PPM tag was detected and the code displayed on the VR100. The validation was done to confirm each fish had a tag with the correct tag code and was in the correct labeled bucket. Having only one or two fish in each bucket facilitated a faster validation process by reducing the opportunity for collisions of the emitted codes. After tag validation, the two buckets with the same identification number were combined into one 19-L (5-gal) perforated bucket such that each perforated bucket contained three tagged Chinook Salmon. Buckets were perforated with ¼-in (6.4-mm) holes starting 15 cm from the bottom to allow water exchange during transport. Each bucket was covered with a snap-on lid and had a label that reflected where the bucket was to be placed in the transport truck, as well as which holding can it was to be placed in at the holding site.

## Fish transport

Fish were moved into the transport tank or tanks on the flatbed truck (Figure 4) immediately after the fish were combined into one perforated bucket. Water was continuously pumped from the nearby hatchery raceway to the transport tank or tanks to allow the fish to hold in the tank until all fish from that session had been tagged. Once all the tagging for each shift was completed, fish were transported to the release site (Table 1). The first group was transported in two smaller transport tanks, each of which held twenty-one 19-L buckets, on an 8-m (26-ft) flatbed truck (Table 1). The second group was transported in one larger transport tank which held thirty 19-L buckets on a similar sized flatbed truck.

Dummy-tagged fish were transported with the study fish (Table 1). Temperature and dissolved oxygen were taken at the MKRH after loading but before leaving for the release site and at the release site prior to unloading fish from the transport truck (Table 2). Temperature was continuously measured in the transport tanks during each transport (Appendix C).

## Fish holding at release sites

Once the transport trucks arrived at Durham Ferry, the perforated buckets containing the tagged fish were transferred into a bucket “sleeve” (i.e., a non-perforated bucket of the same size) half full of river water in the bed of a pickup truck (Figure 5). The pickup truck was then driven to the water’s edge, where buckets were unloaded (Figure 5). Once unloaded from the pickup truck, perforated buckets within sleeves were carried to the river’s edge where crew took them out of the sleeves, and transferred them to the perforated holding cans staged in the river (Figure 6).

Five buckets of salmon were put into each 121-L perforated holding can, for a total of 15 fish/can. Each tagging session had 27 buckets that were put into 6 perforated holding cans (similar to those used at MKRH for fish holding), for a total of 54 buckets in 11 perforated holding cans/day (some from each session went into the same holding can). Each tagging session also included 6–21 dummy-tagged fish which were placed into 1 or 2 additional perforated holding cans per day. A holding density of fifteen salmon per can during the holding period was within the recommended holding density of less than 15 g/L (Peven et al. 2005). Fish were held in the river for a minimum of 24 h prior to releasing the first group of fish.

## Releases

Fish releases occurred every 6 h (1900, 0100, 0700, and 1300 hours) after fish had been held for a minimum of 24 h (Table 1). Releases were made by placing perforated holding cans in “sleeves” (similar idea to those used for perforated buckets) and moving the cans downstream by boat to assure fish were released in the middle of the channel and downstream of the holding area (Figure 7). Perforated holding cans were placed in sleeves to avoid predators from following the scent of the fish in the perforated holding can as it was moved downstream. Because of the low water, perforated holding cans inside the sleeves were pulled part-way out of the water during boat movement downstream so holding cans within sleeves did not hit the bottom of the river during transit (Figure 7).

During 2014, receivers were deployed downstream of the release location to confirm that tags were still functioning at the time of release. A HR receiver was used at this location to detect the tags. There were also receivers deployed upstream of the release site to document tags moving upstream, indicating they were likely inside a predator. A total of 1,918 juvenile Chinook Salmon tagged with VEMCO V4 acoustic tags were released into the San Joaquin River at Durham Ferry in mid-April through mid-May of 2014: 643 on April 16–20, 646 on April 30–May 4, and 629 on May 15–19 (Table 1).

## Dummy-tagged fish

Salmon were tagged at the hatchery with dummy tags for three purposes: to assess fish condition after transport and holding, to assess fish health at the hatchery and after transport and holding, and to monitor tag retention.

### Fish Condition Assessments

In order to evaluate the effects of tagging, transportation, and release, several groups of juvenile salmon were implanted with inactive dummy transmitters. Dummy tags were systematically interspersed into the tagging order for each tag group (Table 1). Procedures for tagging these fish, transporting them to the release site, and holding them at the release site were the same as for fish with active transmitters.

A total of 135 fish (45 fish/week; 15 fish/day) were tagged with dummy tags to assess general condition after tagging, transport, and holding at the release site (Table 1). Dummy-tagged fish were transported with the groups implanted with live tags and held at the release site for 48 h prior to assessment. Six characteristics were used to assess fish condition of the dummy-tagged fish (Table 3). Unlike previous studies, dummy-tagged fish were moved half way out to the release site and back before assessment to better replicate handling of the study fish (Figure 8). In addition, dummy-tagged fish were evaluated for surgical techniques after they were assessed for fish condition. Each fish was examined to see if the sutures were still present, whether there was any incision apposition, presence and location of any fungus, organ damage, peritoneal apposition, or signs of tag expulsion (Table 4).

### Fish Health

An additional thirty fish per week (total of 90) were dummy-tagged, transported to the release site with the fish that had active tags, and held for 48 h prior to assessment for pathogens (gill parasites, viruses and bacteria) and smolt physiology (gill $Na^{+}/K^{+}$-ATPase) by the USFWS California-Nevada Fish Health Center (CA-NV FHC; Appendix D:). Fish were assessed on April 19, May 4, and May 19, 2014. Fish were euthanized, FL was recorded, any abnormalities were noted, and tissue was sampled for lab assays.

### *Lab Assays*

Bacteriology — A sample of kidney tissue was collected aseptically and inoculated onto brain-heart infusion agar. Bacterial isolates were screened by standard microscopic and biochemical tests (USFWS and AFS-FHS 2010). These screening methods would not detect *Flavobacterium columnare. Renibacterium salmoninarum* (the bacteria that causes bacterial kidney disease) was screened by a fluorescent antibody test of kidney imprints.

Virology — Pooled samples of kidney and spleen from three fish were inoculated onto EPC and CHSE-214 at 15°C as described in the AFS Bluebook (USFWS and AFS-FHS 2010) with the exception that no blind pass was performed.

Histopathology — Tissues were removed from the fish and immediately fixed in Davidson's fixative. In the lab, the tissues were processed for 5 µm paraffin sections and stained with hematoxylin and eosin (Humason 1979). All tissues for a given fish were placed on one slide and identified by a unique code number. Each slide was examined under a light microscope and observations of abnormalities were noted. In Chinook Salmon release groups, gill, kidney, liver, and intestine tissues from ten fish per group were examined for parasite infection or other abnormalities.

Gill ATPase — Gill $Na^+/K^+$-Adenosine Triphosphatase (gill ATPase) activity was assayed by the method of McCormick (1993). Gill ATPase activity is correlated with osmoregulatory ability in saltwater, and high concentrations are found in the chloride cells of the lamellae.

## Tag Retention Fish

Another 75 fish (25 fish/surgeon) were tagged with dummy tags and held at the MKRH to evaluate delayed mortality, fish condition, and surgical techniques. The fish were held for 33 d in two 2,271-L (600-gal) tanks that were divided in half to accommodate three surgeon specific sections. Each dummy tag was color coded by surgeon. Twenty-five untagged control fish were added to each of the three sections. The 75 tag retention fish were dummy-tagged on April 14, 2014. The fish condition assessments and necropsies were performed on these dummy-tagged fish on May 17, 2014. Fish condition characteristics were the same as for dummy-tagged fish taken to the release sites (Table 3). Necropsies were performed on each fish after condition assessments to evaluate surgical techniques. The scoring rubric to assess surgical technique was slightly different than that used at the release sites

(Table 4), and included the following criteria: presence of sutures, suture pattern irritation at suture points, incision apposition, incision healing, fungus presence and (if applicable) location, organ inclusion, signs of tag expulsion, and signs of disease. The control fish were not necropsied, but scoring for fish condition (Table 3) was also conducted on May 17, 2014. Internal and external pictures were taken for all necropsied fish.

## Tag Detection

Acoustic tags were detectable on hydrophones located at 38 stations throughout the lower San Joaquin River and Delta to Chipps Island (i.e., Mallard Slough) and Benicia Bridge (Figure 9, Table 5). Detection data were also available from 150 acoustic tags implanted by NMFS (Hayes et al. 2017: Ch. 2) into several species of predatory fish released in the Delta in April–May 2014: 37 Striped Bass *Morone saxatilis*, 66 Largemouth Bass *Micropterus salmoides*, 18 Channel Catfish *Ictalurus punctatus*, and 29 White Catfish *Ameiurus catus*. Detections of acoustic-tagged predatory fish were used to characterize the variability of predator behavior, and to assess the sensitivity of the predator filter.

## Statistical Methods

### Data Processing for Survival Analysis

The University of Washington received the database of tagging and release data from the US Fish and Wildlife Service. The tagging database included the date and time of tag activation and tagging surgery for each tagged Chinook Salmon released in 2014, as well as the name of the surgeon for each fish and the date and time of release of the tagged fish to the river. Fish size (FL and weight), tag weight (in air), and any notes about fish condition were included, as well as the survival status of the fish after transport and at the time of release. Tag serial number and two unique tagging codes were provided for each tag, representing codes for various types of signal coding. Tagging data were summarized according to release group and surgeon, and were cross-checked by Denise Barnard (USFWS) and Pat Brandes (USFWS) for quality control.

Acoustic tag detection data collected at individual monitoring sites (Table 5) were transferred to the U.S. Geological Survey (USGS) in Sacramento, California. A multiple-step process was used to identify and verify detections of fish in the data files and produce summaries of detection data suitable for converting to tag detection histories. Detections were classified as valid if two or more transmissions were recorded within a 30-min time frame on the hydrophones comprising a detection site from any of the tag codes associated with the tag. The University of Washington received the primary database of autoprocessed detection data from the USGS. These data included the date, time, location, and tag codes and serial number of each valid detection of the acoustic Chinook Salmon tags on the fixed site receivers. The tag serial number indicated the acoustic tag ID and was used to identify tag activation time, tag release time, and release group from the tagging database.

The autoprocessed database was cleaned to remove obviously invalid detections. The University of Washington identified potentially invalid detections based on unexpected travel times or unexpected transitions between detections, and queried the USGS processor about any discrepancies. All corrections were noted and made to the database. All subsequent analyses were based on this cleaned database.

After the survival analysis was complete and the draft report written, it was discovered in August 2017 that some HR detections had not been processed. Detailed survival results in this report do not represent those missing detections. The missing detections were processed in autumn 2017, and the effects of those additional detections on the survival results were summarized under *Results – Detections of Acoustic-Tagged Fish*.

The information for each tag in the database included the date and time of the beginning and end of each detection event when a tag was detected. Unique detection events were distinguished by detection on a separate hydrophone or by a time delay of 30 min between repeated hits on the same receiver. Separate events were also distinguished by unique signal coding schemes (e.g., PPM vs. HR). The cleaned detection event data were converted to detections denoting the beginning and end of receiver array "visits," with consecutive visits to an array separated either by a gap of 12 h or more between detections on the array, or by detection at a different array. Detections from receivers in dual or redundant arrays were pooled for this purpose, as were detections using different tag coding schemes.

The same data structure and data processing procedure was used to summarize detections of the acoustic-tagged predator fish. Detections of the predatory fish were compared to detections of the Chinook Salmon tags to assist in distinguishing between detections of salmon and detections of predators.

### *Distinguishing between Detections of Chinook Salmon and Predators*

The possibility of predatory fish eating tagged study fish and then moving past one or more fixed site receivers complicated analysis of the detection data. The Chinook Salmon survival model depended on the assumption that all detections of the acoustic tags represented live juvenile Chinook Salmon, rather than a mix of live salmon and predators that temporarily had a salmon tag in their gut. Without removing the detections that came from predators, the survival model would produce potentially biased estimates of survival of actively migrating juvenile Chinook Salmon through the Delta. The size and direction of the bias would depend on the amount of predation by fish and their spatial distribution after eating the tagged salmon. In order to minimize bias, the detection data were filtered for predator detections, and detections assumed to come from predators were identified.

The predator filter used for analysis of the 2014 data was based on the predator filter designed and used in the analyses of the 2011, 2012, and 2013 data (SJRGA 2013; Buchanan et al. 2015, 2016). Those predator filters in turn were based on predator analyses presented by Vogel (2010, 2011), as well as conversations with fisheries biologists familiar with the San Joaquin River and Delta regions and the predator decision processes used in previous years (SJRGA 2010, 2011). The filter was applied to all detections of all tags. Two data sets were then constructed: the full data set including all detections, including those classified as coming from predators (i.e., "predator-type"), and the reduced data set, restricted to those detections classified as coming from live Chinook Salmon smolts (i.e., "smolt-type"). The survival model was fit to both data sets separately. The results from the analysis of the reduced "smolt-type" data set are presented as the final results of the 2014 Chinook Salmon tagging study. Results from analysis of the full data set including "predator-type" detections were used to indicate the degree of uncertainty in survival estimates arising from the predator decision process.

The predator filter was based on assumed behavioral differences between salmon smolts and predators such as Striped Bass and White Catfish. All detections were considered when implementing the filter, including detections from acoustic receivers that were not otherwise used in the survival model. As part of the decision process, environmental data including river flow, river stage, and water velocity were examined from several points throughout the Delta (Table 6), as available. Hydrologic data were downloaded from the California Data Exchange Center website (http://cdec.water.ca.gov/selectQuery.html) and the California Water Data Library (www.water.ca.gov/waterdatalibrary/) on July 18, 2016. Environmental data were reviewed for quality, and obvious errors were omitted.

For each tag detection, several steps were performed to determine if it should be classified as predator or salmon. Initially, all detections were assumed to be of live smolts. A tag was classified as a predator upon the first exhibition of predator-type behavior, with the acknowledged uncertainty that the salmon smolt may actually have been eaten sometime before the first obvious predator-type detection. Once a detection was classified as coming from a predator, all subsequent detections of that tag were likewise classified as predator detections. The assignment of predator status to a detection was made conservatively, with doubtful detections classified as coming from live salmon. In general, the decision process was based on the assumptions that (1) salmon smolts were unlikely to move against the flow, and (2) salmon smolts were actively migrating and thus wanted to move downriver, although they may have temporarily moved upstream with reverse flow.

A tag could be given a predator classification at a detection site on either arrival or departure from the site. A tag classified as being in a predator because of long travel time or movement against the flow was typically given a predator classification upon arrival at the detection site. On the other hand, a tag classified as being in a predator because of long residence time was given a predator classification upon departure from the detection site. Because the survival analysis estimated survival within reaches between sites, rather than survival during detection at a site, the predator classifications on departure from a site did not result in removal of the detection at that site from the reduced data set. However, all subsequent detections were removed from the reduced data set.

The predator filter used various criteria on several spatial and temporal scales, as described in detail in previous reports (e.g., SJRGA 2013; Buchanan et al. 2015, 2016). Criteria fit under various categories, described in more detail in SJRGA (2013): fish speed, residence time, upstream transitions, other unexpected transitions, travel time since release, and movements against flow. The criteria used in the 2011, 2012, and 2013 studies were updated to reflect river conditions and observed tag detection patterns in 2014 (Table 7). There were several new receiver sites installed in 2014 that were added to the predator filter: WCL (B3) = West Canal, OSJ (B5) = Old River at the San Joaquin, MZT (T2) = Montezuma Slough, SBS (T3) = Spoonbill Slough, BBR (G3) = Benicia Bridge, and seven receiver sites used for the NMFS predator removal study (RS4–RS10, model codes N1–N7) (Figure 9). The criteria newly developed for the 2013 study were retained for the 2014 study, including the maximum total visit length at a site (combined over multiple visits), time between visits to the same site, and large-scale movements from different regions of the study area. Unless otherwise specified, the maximum total visit length at a site was limited to 360 h (approximately 15 d); upstream of the Turner Cut junction, the maximum total visit length was equated to the maximum regional residence time allowed upon departure from the site in question.

Certain large-scale tag movements were not allowed for smolt-type detections, including movements from the interior Delta to the San Joaquin River upstream of the mouth of Old River. Tags should not move from the lower San Joaquin River (i.e., from near Stockton or points downstream) to Old River or the interior Delta via the head of Old River, and tags that leave the lower San Joaquin River for the interior Delta should not then return to the San Joaquin River upstream of the mouth of Old River, or move to the upstream sites in Old River (i.e., ORE, ORS, or MRH). Additionally, tags detected in the interior Delta other than at the facilities should not have previously been detected at the facilities after detection in the lower San Joaquin River; that is, tags that arrive at the facilities from the lower San Joaquin River should not later be detected outside the facilities. Tags detected at receivers in the San Joaquin River upstream of the Turner Cut and MacDonald Island receivers should not have been previously detected in the northern or western regions of the South Delta (ORS, MRH, CVP, RGU/RGD, WCL, OR4, MR4, FRE/FRW, JPE/JPW, MAE/MAW, TMN/TMS). The other criteria are specified below and in Table 7.

The criteria used in the predator filter were spatially explicit, and different limits were defined for different receivers and transitions (A and B). General components of the approach to various regions are described below. Only regions with observed detections are described; rule components that follow the general guidelines described in SJRGA (2013) are not highlighted here.

DFU, DFD = Durham Ferry Upstream (A0) and Durham Ferry Downstream (A2): ignore flow and velocity measures, allow long travel time to accommodate initial disorientation after release, and allow few if any repeat visits.

BCA, MOS, and HOR = Banta Carbona (A3), Mossdale (A4), and Head of Old River (B0): allow longer residence time at B0 if next transition is directed downstream. Allow limited transitions to B0 from the Lathrop receiver in the San Joaquin River (A5).

SJL = San Joaquin River near Lathrop (A5): Maximum total visit length = 159 h.

ORE = Old River East (B1): no previous detections in lower San Joaquin River (near Stockton or farther downstream). Maximum total visit length = 92 h.

RS4 – RS10 = Predator Removal Study sites (N1–N7): upstream transitions are allowed from adjacent sites but require short (<20 h) regional residence time on departure from downstream site, and following transition must be directed downstream. Maximum total visit length = 282 h for N1, 360 h otherwise.

SJG = San Joaquin River at Garwood Bridge (A6): transitions from upstream require low flow/velocity on arrival and previous departure.

SJNB, RRI = San Joaquin River at Navy Bridge Drive (A7) and Rough and Ready Island (R1): allow longer residence time if arrive at slack tide; repeat visits to SJNB require arriving with opposite flow and velocity conditions to departure conditions; repeat visits are not allowed at RRI.

MAC, MFE/MFW, TCE/TCW = MacDonald Island (A8), Medford Island (A9), and Turner Cut (F1): allow more flexibility (longer residence time, transition time) if transition water velocity was low. Repeated visits require arriving with opposite flow and velocity conditions to departure conditions. Entry to Turner Cut requires flow directed into Turner Cut. Maximum total visit length = 60 h (MAC, TCE/TCW), or 120 h (MFE/MFW).

ORS, MRH, WCL, OR4, MR4, MID = Old River South (B2), Middle River Head (C1), West Canal (B3), Old River near Highway 4 (B4), and Middle River near Highway 4 (C2) and at Middle River (C3): repeated visits require arriving with opposite flow and velocity conditions to departure conditions, and are not allowed at MRH. The tag should not have been previously detected at the facilities after coming from lower San Joaquin River.

OSJ = Old River at the San Joaquin (B5): repeat visits are not allowed; no restrictions on previous transitions. Maximum total visit length = 44 h.

CVP = Central Valley Project (E1): allow multiple visits; transitions from downstream Old River should not have departed Old River site or arrived at CVP against flow or if not pumping; no repeat visits if not pumping.

JPE/JPW, FRE/FRW = Jersey Point (G1), False River (H1): mean total visit length = 112 h (JPE/JPW), 114 h (FRE/FRW) (based on maximum mid-field residence time); transitions from MFE/MFW, MAC, and TCE/TCW should not have previously moved from the lower San Joaquin River to the facilities or northwest region of the south Delta.

TMN/TMS, MZT, SBS = Threemile Slough (T1), Montezuma Slough (T2), and Spoonbill Slough (T3): repeated visits to TMN/TMS require arriving with opposite flow and velocity conditions to departure conditions. Maximum total visit length = 20 h (TMN/TMS), 33 h (MTZ), or 2 h (SBS).

MAE/MAW, BBR = Chipps Island (G2), Benicia Bridge (G3): should not arrive against strong negative water velocity/flow. Maximum total visit length = 50 h.

The predator scoring and classification method used for the 2011, 2012, and 2013 studies was used again for the 2014 study, resulting in tags being classified as in either a predator or a smolt upon arrival at and departure from a given receiver site and visit; for more details, see SJRGA (2013). All detections of a tag subsequent to its first predator designation were also classified as coming from a predator.

### *Constructing Detection Histories*

For each tag, the detection data summarized on the "visit" scale were converted to a detection history (i.e., capture history) that indicated the chronological sequence of detections on the fixed site receivers throughout the study area. In cases in which a tag was observed passing a particular receiver or river junction multiple times, the detection history represented the final route of the tagged fish past the receiver or river junction. In particular, if a fish was observed far downstream in one route but then returned to the river junction and finally selected the other route, then survival and detection in the later route were modeled. Detections from the receivers comprising certain dual arrays were pooled, thereby converting the dual arrays to redundant arrays: the San Joaquin River just downstream of the release site at Durham Ferry (DFD, site A2), at Banta Carbona (BCA, site A3), and near Mossdale Bridge (MOS, site A4). For one release group, a better model fit was found by pooling detections from the dual array at the Lathrop site (SJL, site A5). There were too few detections at the radial gates at the entrance to Clifton Court Forebay to model the effect of gate status (open or closed) on arrival and transition parameters there in 2014. Detections on the receivers located in the San Joaquin River just upstream of the head of Old River (B0) were used in determining the detection histories, but were later omitted from the survival model.

## Survival Model Development

A multi-state statistical release-recapture model was developed and used to estimate Chinook Salmon smolt survival and migration route parameters throughout the study area. The model is based on the multi-state release-recapture models used in previous Chinook Salmon tagging studies (SJRGA 2013; Buchanan et al. 2015, 2016), but simplified to the reduced data structure observed in 2014.

Although the 2014 study placed receivers at most of the sites used in previous years, there were few or no detections at many of the interior Delta and downstream sites; this required simplification of the model.

Most sites used in previous Chinook Salmon tagging studies were also monitored in the 2014 study. Exceptions were the entrance to Paradise Cut (monitored in 2011: SJRGA 2013), the San Joaquin River Shipping Channel (monitored in 2013: Buchanan et al. 2016), Middle River at Empire Cut (monitored in 2012 and 2013: Buchanan et al. 2015, 2016), and Old River north of Highway 4 (monitored in 2012: Buchanan et al. 2015). Paradise Cut was inaccessible to salmon migrating down the San Joaquin River in 2014 because of low flows. New receiver locations used in 2014 were in West Canal just downstream of the entrance channel to Clifton Court Forebay (WCL = B3), in Old River near its mouth at the San Joaquin River (OSJ = B5), in Montezuma and Spoonbill sloughs just upstream of Chipps Island (MTZ = T2 and SBS = T3, respectively), and Benicia Bridge downstream of Chipps Island (BBR = G3) (Table 5, Figure 9). Additional detections were available from seven new receiver stations in the San Joaquin River between Lathrop (SJL = A5) and Garwood Bridge (SJG = A6); the new receivers (RS4 = N1 through RS10 = N7) were part of a predation study conducted by the National Marine Fisheries Service in 2014 (Hayes et al. 2017).

As in previous years, the San Joaquin River receivers just upstream of the head of Old River (HOR = B0) were omitted from the survival model. The predation study receivers (RS4–RS10) were omitted from the primary analysis, but detections at receiver RS7 (=N4) were used to interpret estimated survival in the San Joaquin River between Lathrop and Garwood Bridge. Interior Delta receivers in the northern Old and Middle rivers (OSJ and MID, respectively) were also omitted from the survival model, but were used to interpret estimated survival and transition probabilities. As in previous years, detections in Threemile Slough (TMN/TMS = T1) were omitted, as were detections in Montezuma Slough (MTZ = T2) and Spoonbill Slough (SBS = T3). The new receiver in West Canal (WCL = B3) would have been used in the survival model had there been more detections there; sparse data meant that it was omitted from the survival model, along with most other interior Delta receivers. Unlike in previous years, the receivers in Burns Cutoff around Rough and Ready Island (RRI = R1) were included in analysis in 2014 because a number of tags were observed using Burns Cutoff rather than the San Joaquin River past the Navy Drive Bridge (SJNB = A7). Also, the new detection site at Benicia Bridge (BBR = G3) was used to provide information on the detection probability at Chipps Island. Although a number of sites were omitted from the survival model as described here, all sites with detections were used in the predator filter.

A rock barrier was installed at the head of Old River in 2014; it effectively blocked access to the Old River route for most Chinook Salmon. There were few detections in Old River, and fewer than 5 detections at either the CVP or the Clifton Court Forebay radial gates. No tags were detected at Highway 4 in Old River, and no tags were detected at any of the receivers in Middle River. Thus, all of the receivers at the water export facilities, at Highway 4, and in Middle River were omitted from the survival model. Furthermore, only one tag was detected at Jersey Point, and none were detected at False River. Thus, those two sites were also omitted from the survival model.

The resulting survival model is considerably simplified compared to the full multi-part, multi-state release-recapture model presented in Buchanan et al. (2015). The full model that includes all routes possible to have been modeled using the available receivers, and the simplified model actually used in analysis of the 2014 data, are both presented below. The full release-recapture model is a simplified version of the model used to analyze the 2012 Chinook Salmon data (Buchanan et al. 2015). It is composed of two submodels; the primary model (Submodel I) accounts for the large-scale movements and survival through the Delta, while the secondary model (Submodel II) focuses on movement and survival in the San Joaquin River downstream of Stockton. Figure 9 shows the layout of the receivers using both descriptive labels for site names and the code names used in the survival model (Table 5). The survival model represents movement and perceived survival throughout the study area to the primary exit point at Chipps Island (i.e., Mallard Island) (Figure 10, Figure 11, and Figure 12). Individual receivers comprising dual arrays were identified separately, using “a” and “b” to represent the upstream and downstream receivers, respectively. Some sites were omitted from the full survival model, as described above, although all were used in the predator filter. The following description of fish movement routes through the Delta includes all routes monitored in 2014, although some were subsequently omitted from the model because no tags were detected in those routes.

Fish moving through the Delta toward Chipps Island may have used any of several routes. The two primary routes modeled were the San Joaquin River route (Route A) and the Old River route (Route B). Route A followed the San Joaquin River past the distributary point with Old River near the town of Lathrop, and past the city of Stockton. Downstream of Stockton, fish in the San Joaquin River route (Route A) may have remained in the San Joaquin River past its confluence with the Sacramento River and on to Chipps Island. Alternatively, fish in Route A may have exited the San Joaquin River for the interior Delta at any of several places downstream of Stockton, including Turner Cut, Columbia Cut (just upstream of Medford Island), and the confluence of the San Joaquin River with either Old River or Middle River, at Mandeville Island. Of these four exit points from the San Joaquin River between Stockton and Jersey Point, Turner Cut and the confluence of the San Joaquin River with Old River were monitored. Turner Cut was assigned a route name (F, a subroute of route A), and survival from Turner Cut to Chipps Island through subroute F was modeled. The route through the confluence of the San Joaquin with Old River (or, the Old River mouth, site OSJ) was not modeled because only a single receiver line was used at this junction (Figure 9), and the data structure was not available to estimate route selection at this junction; in particular, a dual receiver array was required at OSJ, and a comparable array placed downstream of this junction in the San Joaquin River. The Middle River mouth and Columbia Cut were not monitored in 2014. Fish that entered the interior Delta from any of these four exit points may have either moved north through the interior Delta and reached Chipps Island by returning to the San Joaquin River and passing Jersey Point and the junction with False River, or they may have moved south through the interior Delta to the state or federal water export facilities, where they may have been salvaged and trucked to release points on the San Joaquin or Sacramento rivers just upstream of Chipps Island. All of these possibilities were included in both subroute F and route A. However, only two tags were detected on the Turner Cut receivers in 2014, which were too few to estimate the subsequent transition probability, so subroute F was omitted from the model for the analysis of the 2014 data.

For fish that entered Old River at its distributary point on the San Joaquin River just upstream of Lathrop (route B), there were several pathways available to Chipps Island. These fish may have migrated to Chipps Island either by moving northward in either the Old or Middle rivers through the interior Delta, or they may have moved to the state or federal water export facilities to be salvaged and trucked. The Middle River route (subroute C) was monitored and contained within Route B. Passage through the State Water Project (SWP) via Clifton Court Forebay was monitored at the entrance to the forebay and assigned a route (subroute D). Likewise, passage through the federal CVP was monitored at the entrance trash racks and in the facility holding tank and assigned a route (subroute E). Subroutes D and E were both contained in subroutes C (Middle River) and F (Turner Cut), as well as in primary routes A (San Joaquin River) and B (Old River). All routes and subroutes included multiple unmonitored pathways for passing through the Delta to Chipps Island.

Several exit points from the study area were monitored and given route names for convenience, although they did not determine unique routes to Chipps Island. The first exit point encountered was False River, located off the San Joaquin River just upstream of Jersey Point. Fish entering False River from the San Joaquin River entered the interior Delta at that point, and would not be expected to reach Chipps Island without subsequent detection in another route. Thus, False River was considered an exit point of the study area, rather than a waypoint on the route to Chipps Island. It was given a route name (H) for convenience. Likewise, Jersey Point, Chipps Island, and Benicia Bridge were not included in unique routes. Jersey Point was included in many of the previously named routes (in particular, routes A and B, and subroutes C and F), whereas Chipps Island (the final Delta exit point) and Benicia Bridge (downstream of the Delta) were included in all previously named routes and subroutes except route H. Thus, Jersey Point, Chipps Island, and Benicia Bridge were given their own route name (G). Receivers located in Threemile Slough, Montezuma Slough, and Spoonbill Slough (Route T) were not used in the survival model. The routes, subroutes, and study area exit points are summarized as follows:

A = San Joaquin River: survival

B = Old River: survival

C = Middle River: survival

D = State Water Project: survival

E = Central Valley Project: survival

F = Turner Cut: survival

G = Jersey Point, Chipps Island, Benicia Bridge: survival, exit point

H = False River: exit point

T = Threemile Slough, Montezuma Slough, Spoonbill Slough: not used in survival model

R = Rough and Ready Island: survival

The release-recapture model used parameters that denote the probability of detection ( $P_{hi}$ ), route entrainment ( $\psi_{hl}$ ), Chinook Salmon survival ( $S_{hi}$ ), and transition probabilities equivalent to the joint probability of movement and survival ( $\phi_{kj,hi}$ ) (Figure 10, Figure 11, Figure 12, and Table E1). For each dual array, unique detection probabilities were estimated for the individual receivers comprising the array: $P_{hia}$ represented the detection probability of the upstream array at station $i$ in route $h$, and $P_{hib}$ represented the detection probability of the downstream array.

The model parameters are:

$P_{hi}$ = detection probability: probability of detection at telemetry station $i$ within route $h$, conditional on surviving to station $i$, where $i$ = $ia$, $ib$ for the upstream, downstream receivers in a dual array, respectively.

$S_{hi}$ = perceived survival probability: joint probability of migration and survival from telemetry station $i$ to $i$+1 within route $h$, conditional on surviving to station $i$.

$\psi_{hl}$ = route entrainment probability: probability of a fish entering route $h$ at junction $l$ ($l$ =1, 2), conditional on fish surviving to junction $l$.

$\phi_{kj,hi}$ = transition probability: joint probability of route entrainment and survival; the probability of migrating, surviving, and moving from station $j$ in route $k$ to station $i$ in route $h$, conditional on survival to station $j$ in route $k$.

$\lambda$ = joint transition and detection probability: joint probability of moving downstream from Chipps Island, surviving to Benicia Bridge, and detection at Benicia Bridge, conditional on survival to Chipps Island.

The complexity of the routing from the region near the Turner Cut junction on the San Joaquin River (i.e., starting from MacDonald Island and Turner Cut) makes it easiest to depict the possible routes using two submodels. Submodel I represents detailed transitions in the upper reaches of the San Joaquin River and in the Old River route, and large-scale transitions in the San Joaquin River route from Garwood Bridge (SJG = A6) (Figure 10). The parameter $S_{A6,G2}$ in Submodel 1 represents the probability of getting from Garwood Bridge to Chipps Island, regardless of route (Figure 10). Submodel II decomposes the survival probability from Garwood Bridge to Chipps Island into reach-specific survival and transition probabilities, using detections from MacDonald Island (MAC = A8), Medford Island (MFE/MFW = A9), Turner Cut (TCE/TCW = F1), and Chipps Island (MAL = G2) (Figure 11). Submodel II also uses detections of tags that used the San Joaquin River route at the head of Old River but were later detected at the water export facilities (subroutes E and D), and those that were detected at Jersey Point (G1) or False

River (H1). Submodel II also uses Burns Cutoff as an alternative route to the San Joaquin River around Rough and Ready Island (Figure 11).

In 2014, there were sparse data in the interior and lower Delta. In particular, there were no detections in Middle River or False River in 2014, and very few detections at Turner Cut, Jersey Point, the SWP, and the CVP. The routes and subroutes restricted to these detection sites were thus omitted from the model. Furthermore, only two to three tags were detected at either MacDonald Island or Turner Cut in 2014, and only one tag was detected at Medford Island. Thus, it was not possible to model transition probabilities from those sites to Chipps Island. The resulting release-recapture model was considerably simpler than the full model that consisted of Submodel I and Submodel II, and used detections only at the sites upstream of the head of Old River, the San Joaquin River sites at Lathrop (SJL = A5), Garwood Bridge (SJG = A6), and the Navy Drive Bridge (SJNB = A7), in Burns Cutoff at Rough and Ready Island (RRI = R1), in Old River at its head (ORE = B1) and at the head of Middle River (ORS = B2), and at Chipps Island (MAL = G2) and Benicia Bridge (BBR = G3) (Figure 12). Even with this reduced model structure, some parameters could not be estimated for some release groups.

In addition to the model parameters, derived performance metrics measuring migration route probabilities and survival were estimated as functions of the model parameters. Both route selection and route-specific survival were estimated for the two primary routes determined by routing at the head of Old River (routes A and B):

$\psi_A = \psi_{A1}$ : probability of remaining in the San Joaquin River at the head of Old River,

$\psi_B = \psi_{B1}$ : probability of entering Old River at the head of Old River.

The probability of surviving from the entrance of the Delta near Mossdale Bridge (site A4, MOS) through an entire migration pathway to Chipps Island was estimated as the product of survival probabilities that trace that pathway:

$S_A = S_{A4} S_{A5} S_{A6,G2}$ : Delta survival for fish that remained in the San Joaquin River past the head of Old River,

$S_B = S_{A4} \phi_{B1,B2} S_{B2,G2}$ : Delta survival for fish that entered Old River at its head.

The parameter $S_{A6,G2}$ represents the probability of getting to Chipps Island (i.e., Mallard Island, site MAE/MAW) from site A6 (SJG). This parameter represents multiple pathways around or through the Delta to Chipps Island, as well as both the San Joaquin River route and the Burns Cutoff route past Rough and Ready Island (Figure 9):

$$S_{A6,G2} = S_{A6}\left(\psi_{A2} S_{A7,G2} + \psi_{R2} S_{R1,G2}\right) ,$$

where $S_{A7,G2}$ and $S_{R1,G2}$ represent the survival from the Navy Drive Bridge receivers on the San Joaquin River (SJNB = A7) and the receivers in Burns Cutoff at Rough and Ready Island (RRI = R1), respectively, to Chipps Island. Fish that were present at either site A7 or site R1 may have remained in the San Joaquin River all the way to Chipps Island, or they may have entered the interior Delta at Turner Cut or downstream of Turner Cut. Fish that entered the interior Delta either at Turner Cut or farther downstream may have migrated through the interior Delta to Chipps Island via Frank's Tract or Fisherman's Cut, False River, and Jersey Point, returned to the San Joaquin River via its downstream confluence with either Old or Middle River at Mandeville Island, or gone through salvage and trucking from the water export facilities[1]. All such routes are represented in the $S_{A7,G2}$ and $S_{R1,G2}$ parameters, which were estimated directly from the release-recapture model (Figure 12).

The parameter $\phi_{B1,B2}$ is the joint probability of surviving from the receivers in Old River at its head (ORE = B1) to the head of Middle River, and remaining in Old River at that junction: $\phi_{B1,B2} = S_{B1}\psi_{B2}$. If no fish entered Middle River at its head, then the transition probability $\phi_{B1,B2}$ reduces to the survival probability $S_{B1}$. However, without detections at site MRH (C1) with which to estimate the detection probability at that site, or an independent estimate of the detection probability, it is not possible to confirm that no fish entered Middle River.

Survival probability $S_{B2,G2}$ represents survival of fish to Chipps Island that entered Old River at its head, subsequently survived to the head of Middle River, and remained in Old River at Middle River (i.e., arrived at site B2, ORS). Fish in this route may have been subsequently salvaged and trucked from the water export facilities, or have migrated through the interior Delta to Jersey Point and on to Chipps Island. Because there were many unmonitored river junctions within the "reach" between site B2 and

[1] No tagged Chinook Salmon were observed moving from the San Joaquin River downstream of Stockton to the receivers in Old and Middle rivers in the interior Delta or to the water export facilities in 2014.

Chipps Island, it was impossible to separate the probability of taking a specific pathway from the probability of survival along that pathway. Furthermore, because of sparse detection data at sites downstream of site B2 in the Old River route (e.g., the export facilities and Highway 4 receivers), it was not possible to decompose the survival probability from B2 to G2 ($S_{B2,G2}$) into reach transition probabilities in 2014.

Using the estimated migration route probabilities and route-specific survival for the two primary routes (A and B), survival of the population from Mossdale (site A4) to Chipps Island was estimated as:

$$S_{Total} = \psi_A S_A + \psi_B S_B .$$

Survival to Benicia Bridge (G3) could not be estimated because it was not possible to estimate the detection probability at that site. However, the joint probability of surviving from Mossdale to Benicia Bridge and being detected there was estimated:

$$\lambda_{A4} = S_{Total} \lambda .$$

The complement of $\lambda_{A4}$ (i.e.,$1 - \lambda_{A4}$) includes both the possibility of mortality between Mossdale and Benicia Bridge and the possibility of surviving to Benicia Bridge but evading detection there.

Unlike previous tagging studies (e.g., SJRGA 2013; Buchanan et al. 2015), it was not possible to estimate survival to the Jersey Point junction in 2014 because there were too few detections at either Jersey Point or False River. Additionally, the low detection counts at MacDonald Island, Turner Cut, the Highway 4 receivers, the CVP, and Clifton Court Forebay made it impossible to estimate survival from any of those sites to Chipps Island. However, it was possible to estimate survival to those sites both for the primary routes defined at the head of Old River and overall, using a separate “Southern Delta” (SD) release-recapture model (Figure 13). The full SD model incorporated the complete data structure possible in the upper reaches of both primary routes, including detections from receivers in Middle River; lack of detections in portions of the Old River route required simplifying the model for parameter estimation. The route-specific SD survival performance metrics are (based on the unsimplified SD model):

$$S_{A(SD)} = S_{A4} S_{A5} S_{A6(SD)} \text{, and}$$

$$S_{B(SD)} = S_{A4} S_{B1} \left( \psi_{B2} S_{B2(SD)} + \psi_{C2} S_{C1(SD)} \right),$$

where $S_{A6(SD)}$, $S_{B2(SD)}$, and $S_{C1(SD)}$ are defined as:

$$S_{A6(SD)} = S_{A6} \left( \psi_{A2} S_{A7} + \psi_{R2} S_{R1} \right),$$

$$S_{B2(SD)} = \phi_{B2,B4} + \phi_{B2,C2} + \phi_{B2,D1} + \phi_{B2,E1},$$

$$S_{C1(SD)} = \phi_{C1,B4} + \phi_{C1,C2} + \phi_{C1,D1} + \phi_{C1,E1}.$$

Lack of detections at site C1 reduced $S_{B(SD)}$ to

$$S_{B(SD)} = S_{A4} \phi_{B1,B2} S_{B2(SD)}.$$

Total survival through the southern Delta was defined as:

$$S_{Total\,(SD)} = \psi_A S_{A(SD)} + \psi_B S_{B(SD)}.$$

Using the SD model, it is possible to estimate the route selection probabilities for the route A subroutes, which have been estimated in previous years (e.g., Buchanan et al. 2015):

$\psi_{AA} = \psi_{A1} \psi_{A3}$: probability of remaining in the San Joaquin River at the head of Old River and at Turner Cut,

$\psi_{AF} = \psi_{A1} \psi_{F3}$: probability of remaining in the San Joaquin River at the head of Old River, and entering Turner Cut at its junction with the San Joaquin River,

where $\psi_{F3} = 1 - \psi_{A3}$.

The probability of reaching Mossdale from the release point at Durham Ferry, $\phi_{A1,A4}$, was defined as the product of the intervening reach survival probabilities:

$$\phi_{A1,A4} = \phi_{A1,A2} S_{A2} S_{A3}.$$

This measure reflects a combination of mortality and possible residualization upstream of Mossdale, although the Chinook Salmon in this study were assumed to be migrating (i.e., no residualization). In cases where the second detection site (A3 = BCA) was removed from analysis, the alternative model parameter $S_{A2,\,A4} = S_{A2}S_{A3}$ was used:

$$\phi_{A1,\,A4} = \phi_{A1,\,A2}S_{A2,\,A4}\,.$$

Individual detection histories (i.e., capture histories) were constructed for each tag as described above. Each detection history consisted of one or more fields representing initial release (field 1) and the sites where the tag was detected, in chronological order. Detection on both receivers (or both lines of receivers, if there were multiple receivers in each line) in a dual array was denoted by the code “ab”, detection on only the upstream receiver was denoted “a0”, and detection on only the downstream receiver was denoted “b0”. For example, the detection history DF A2a0 A5ab A6ab A7a0 A8ab G2b0 G3 represented a tag that was released at Durham Ferry and detected at the first of the two receivers just downstream of the release site (A2a0), both receiver lines in the dual array near Lathrop, (A5ab), both receivers in the San Joaquin River near Garwood Bridge (A6ab), the upstream receiver near the Navy Drive Bridge (A7a), both receivers at MacDonald Island (A8ab), the downstream line of receivers at Chipps Island (G2b0), and one or more receivers at Benicia Bridge. A tag with this detection history can be assumed to have passed by certain receivers without detection: A3a, A3b, A4a, and A4b; the tag may have passed by site A9 (MFE/MFW) without detection, or it may have entered the Interior Delta before passing A9. Likewise, it either passed Jersey Point (G1) or the export facilities via salvage (E1/E2, D1/D2) without detection. However, the 2014 survival models did not model detection and transition to and from those sites. In the primary 2014 survival model (Figure 12), this detection history was parameterized:

$$\phi_{A1,A2}P_{A2a}Q_{A2b}S_{A2}Q_{A3}S_{A3}Q_{A4}S_{A4}\psi_{A1}P_{A5a}P_{A5b}S_{A5}P_{A6a}P_{A6b}S_{A6}\psi_{A2}P_{A7a}Q_{A7b}S_{A7,G2}Q_{G2a}P_{G2b}\lambda,$$

where $Q_{hi} = 1 - P_{hi}$ is the probability of evading detection, conditional on being present at site $i$ in route $h$. In the southern Delta component of the model (Figure 13), this detection history was parameterized identically through site A7, and then incorporated the detection at site A8 instead of the transition to Chipps Island:

$$\phi_{A1,A2}P_{A2a}Q_{A2b}S_{A2}Q_{A3}S_{A3}Q_{A4}S_{A4}\psi_{A1}P_{A5a}P_{A5b}S_{A5}P_{A6a}P_{A6b}S_{A6}\psi_{A2}P_{A7a}Q_{A7b}S_{A7}\psi_{A3}P_{A8a}P_{A8b}$$

A second example is the detection history DF A3 A4 B1ab B2a0. A fish with this detection history was released at Durham Ferry, passed the first receivers without detection, passed the receivers at Banta Carbona (A3) and Mossdale Bridge (A4) with detection, entered Old River and was detected on both receivers at the first Old River site (B1ab) and on the upstream receiver at the Old River South site (B2a0). The fish was not detected again after detection at B2. It may have died before reaching the CVP (E1) or Clifton Court Forebay (D1) or Highway 4 (B4, C2), or it may have arrived at one of those sites without detection either there or subsequently. The primary 2014 model (Figure 12) does not model detections at E1, D1, B4, or C2, so that model gives the following parameterization to this detection history:

$$\phi_{A1,A2} Q_{A2} S_{A2} P_{A3} S_{A3} P_{A4} S_{A4} \psi_{B1} P_{B1a} P_{B1b} \phi_{B1,B2} P_{B2a} Q_{B2b} \chi_{B2},$$

where

$$\chi_{B2} = 1 - S_{B2,G2} + S_{B2,G2} \left(1 - P_{G2}\right)\left(1 - \lambda\right),$$

and

$$P_{G2} = 1 - \left(1 - P_{G2a}\right)\left(1 - P_{G2b}\right) .$$

The SD survival model (Figure 13) models detections at the export facility and Highway 4 receivers rather than detections at Chipps Island and Benicia Bridge. Thus, this detection history has the same parameterization in the SD survival model as in the primary model, with the exception that $\chi_{B2}$ is replaced with $\chi_{B2(SD)}$, where

$$\chi_{B2(SD)} = 1 - \phi_{B2,B4} - \phi_{B2,C2} - \phi_{B2,D1} - \phi_{B2,E1} + \phi_{B2,B4} Q_{B4} \chi_{B4} + \phi_{B2,C2} Q_{C2} \chi_{C2} + \phi_{B2,D1} Q_{D1} \chi_{D1} + \phi_{B2,E1} Q_{E1} \chi_{E1}$$

and $\chi_{hi}$ are defined analogously for $hi$ =B4, C2, D1, and E1.

Under the assumptions of common survival, route entrainment, and detection probabilities, and independent detections among the tagged fish in each release group, the likelihood function for the survival model for each release group is a multinomial likelihood with individual cells denoting each possible capture history.

### *Model Modifications: Release Group 1*

The first release group had no tags detected at the receivers located upstream of Durham Ferry (DFU = A0), so that site was removed from the release-recapture model. No tags were detected in Middle River, so model components involving sites C1 and C2 were removed from the SD model. Detections from the two lines of the dual array at Durham Ferry Downstream (A2) were pooled to improve model fit; the same was done at SJL (A5) and SJG (A6).

### *Model Modifications: Release Group 2*

As was the case for the first release group, the second release group had no tags detected at site A0 (=DFU) or in Middle River (C1, C2), so those sites were removed from the model. Detections from the two receiver lines comprising the dual array at Durham Ferry Downstream (A2) were pooled to improve model fit. No tags were detected at Chipps Island, but one tag was detected at Benicia Bridge. Because no tags were detected at Chipps Island, it was not possible to estimate the detection probability at that site, which in turn precluded estimation of survival to Chipps Island. Because only a single line of receivers was installed at Benicia Bridge in 2014, it was also not possible to the estimate detection probability at that site. Instead, the joint probability of survival to Benicia Bridge was estimable for fish coming from SJNB (A7), RRI (R1), and ORS (B2):

$$\lambda_{A7} = S_{A7,G2} S_{G1,G2} P_{G3} = \phi_{A7,G2} \lambda ,$$
$$\lambda_{R1} = S_{R1,G2} S_{G1,G2} P_{G3} = \phi_{R1,G2} \lambda ,$$
$$\lambda_{B2} = S_{B2,G2} S_{G1,G2} P_{G3} = \phi_{B2,G2} \lambda .$$

### *Model Modifications: Release Group 3*

The mid-May release group had very sparse data downstream of the head of Old River. Thus, all Old River route sites downstream of ORE (B1) were omitted, as were all San Joaquin River sites downstream of Garwood Bridge (SJG = A6).

## Parameter Estimation

The multinomial likelihood model described above was fit numerically to the observed set of detection histories according to the principle of maximum likelihood using Program USER software, developed at the University of Washington (Lady and Skalski 2009). Point estimates and standard errors were computed for each parameter. Standard errors of derived performance measures were estimated using the delta method (Seber 2002:7–9). Sparse data prevented some parameters from being freely estimated for some release groups. Transition, survival, and detection probabilities were fixed to 1.0 or

0.0 in the USER model as appropriate, based on the observed detections. In cases where there were fewer than 3 detections at a given site, the sensitivity of the model results to the detection probability at the site in question was assessed by fitting the model using alternative detection probabilities for that site. Alternative detection probabilities considered were 0.1, 0.5, and 0.9.

The primary model was fit separately for each release. For each release, the complete data set that included possible detections from predatory fish was analyzed separately from the reduced data set restricted to detections classified as Chinook Salmon smolt detections. Population-level estimates of parameters and performance measures that represented the late April and May release groups were estimated by fitting the model to the pooled detection data from the second and third release groups. The mid-April release group was omitted from the population-level estimates because of the high rate of premature tag failure for that group. To account for differences in detection probabilities between the two release groups, unique detection probabilities were estimated for the two release groups, while common survival and route entrainment probabilities were estimated from the pooled data. Simpler models were considered that equated detection probabilities between release groups. Likelihood ratio tests were used to select the most parsimonious model that still fit the pooled data set.

The SD model was fit concurrently for all three release groups, using common parameters across the release groups in the lower reaches of the SD model (i.e., downstream of sites A7, R1, and B2) to compensate for very sparse data in those regions. Other parameters were specific to the release groups. However, detection probabilities were equated at some sites in order to simplify the model; likelihood ratio tests were used to identify parameters that could be equated without loss of model fit. Population-level estimates represented the late April and May release groups, using a procedure similar to that described above for the primary model, but using additional data from the mid-April release group from sites downstream of A7, R1, and B2 (i.e., sites A8, F1, D1, D2, E1, and E2), as described above for the SD model.

For each model fit, goodness-of-fit was assessed visually using Anscombe residuals (McCullagh and Nelder 1989). The sensitivity of parameter and performance metric estimates to inclusion of detection histories with large absolute values of Anscombe residuals was examined for each release group individually.

For each release group and for the pooled data set, the effect of primary route (San Joaquin River or Old River) on estimates of survival to Chipps Island was tested with a two-sided *Z*-test on the log scale:

$$\mathrm{Z} = \frac{\ln\left(\hat{S}_A\right) - \ln\left(\hat{S}_B\right)}{\sqrt{\hat{V}}},$$

where

$$V = \frac{Var\left(\hat{S}_A\right)}{\hat{S}_A^2} + \frac{Var\left(\hat{S}_B\right)}{\hat{S}_B^2} - \frac{2Cov\left(\hat{S}_A, \hat{S}_B\right)}{\hat{S}_A \hat{S}_B}.$$

The parameter *V* was estimated using Program USER. Also tested was whether tagged Chinook Salmon smolts showed a preference for the Old River route using a one-sided *Z*-test with the test statistic:

$$\mathrm{Z} = \frac{\hat{\psi}_B - 0.5}{SE\left(\hat{\psi}_B\right)}.$$

Statistical significance was tested at the 5% level ($\alpha$ = 0.05).

The effect of release group on the values of the model survival and transition probability parameters was examined by testing for a statistically significant decrease in parameter estimates for the third release group compared to the second release group; estimates from the first release group were not considered on account of the tag programming error for that release group. For each model survival and transition probability parameter $\theta$, where $\theta = \phi_{kj,hi}$ or $\theta = S_{hi}$, the difference in parameter values between the second and third release groups was defined as

$$\Delta_\theta = \theta_2 - \theta_3,$$

for model parameter $\theta_R$ for release group $R$ ( $R = 2, 3$ ). The difference $\Delta$ was estimated by $\hat{\Delta}_\theta = \hat{\theta}_2 - \hat{\theta}_3$. The null hypothesis of no difference was tested against the alternative of a positive difference (i.e., higher parameter value for the first release group):

$$H_{0\theta}: \Delta_\theta = 0$$

vs.

$$H_{A\theta}: \Delta_{\theta} > 0 .$$

Only those parameters that were estimated separately for both release groups and were based on at least four detections at the upstream boundary of the reach were considered; these restrictions resulted in tests for parameters $\phi_{A1,A2}$, $S_{A2}$, $S_{A3}$, $S_{A4}$, $S_{A5}$, and the composite parameters $\phi_{A1,A4}$ and $\lambda_{A4}$. A family-wise significance level of α = 0.10 was selected, and the Bonferroni multiple comparison correction was used, resulting in a test-wise significance level of 0.0143 for 7 tests (Sokal and Rohlf 1995).

### Analysis of Tag Failure

The first tag life study (April) indicated a high rate of premature tag failure, which the manufacturer identified to be due to an error in programming of the tag's kill-time counter; the mid-April release group of tags also had this programming error. The programming error was corrected for the final two releases of tags and the later tag-life studies. Five tags could not be activated, and another five tags were activated but were never detected during the tag-life study; these tags have been excluded from the tag-life analysis. This left a total of 102 tags used in the tag-life study analysis: 31 tags from the first study, and 71 from the later studies, pooled. Tags were pooled across tanks for analysis.

Observed tag failure times were used to model tag survival using the 4-parameter vitality curve (Li and Anderson 2009). Because tags from the April tag-life study had the programming error and tags from the May tag-life studies did not, separate tag survival models were fit for the April and May studies. The early May tag-life study and one of the late May tag-life studies used tags whose kill-time counters had been reset, while the other late May tag-life study used tags whose kill-time counters had been extended to 200 d (i.e., longer than expected to be necessary for Chinook Salmon migrants to exit the Delta). The late April/early May release group used tags whose kill-time counters had been reset, while the late May release group used some tags whose kill-time counters had been reset and others whose kill-time counters had been extended. Data from the late May tag-life studies were pooled to improve model fit (based on the Akaike information criterion, AIC), regardless of whether the kill-time counters had been reset or extended (Burnham and Anderson 2002). Also based on AIC, data from the early and late May tag-life studies were pooled to improve model fit. All tag failure times were used to fit the tag survival model (i.e., tag failure times were not right-censored).

The fitted tag survival curve was used to adjust estimated fish survival and transition probabilities for premature tag failure using methods adapted from Townsend et al. (2006). In Townsend et al. (2006), the probability of tag survival through a reach is estimated based on the average observed travel time of tagged fish through that reach. For this study, travel time and the probability of tag survival to Chipps Island was estimated separately for the different routes (e.g., San Joaquin River route and Old River route). Subroutes using truck transport were handled separately from subroutes using only in-river travel. Standard errors of the tag-adjusted fish survival and transition probabilities were estimated using the inverse Hessian matrix of the fitted joint fish-tag survival model. The additional uncertainty introduced by variability in tag survival parameters was not estimated, with the result that standard error estimates may have been slightly low. In previous studies, however, variability in tag-survival parameters was observed to contribute little to the uncertainty in the fish survival estimates when compared with other, modeled sources of variability (Townsend et al. 2006); thus, the resulting bias in the standard errors was expected to be small.

Adjustments for premature tag failure were made using only the tags without the programming error (i.e., the late April/early May and late May release groups using tag life data from the May tag-life studies). The highly accelerated rate of tag failure from the mid-April release group made it inappropriate to attempt to adjust the estimated joint probability of fish survival and tag survival by the estimated tag survival curve from the April tag-life study, for several reasons. First, the travel time distribution estimated using the faulty tags was likely to be biased toward shorter travel times because longer travel times were not observable; thus, any adjustment to the survival estimate would be smaller than was appropriate, and the adjusted survival estimates would remain negatively biased (Holbrook et al. 2013). Additionally, the nature of the tag programming error (i.e., premature initiation of the kill-time counter) meant that tags activated on different days had different probabilities of surviving a given duration since tag activation. In particular, the tags released in the mid-April release group were activated over a period of four days (April 14–17), whereas the tags in the April tag life study were all activated on April 17, 2014, the final day of tag activation of the released tags; it is thus reasonable to assume that the tag survival curve estimated from the April tag-life study represents the survival of the released tags that were also activated on that day, although the estimated travel time for these tags remains biased. However, the nature of the tag programming error means that the released tags that were activated before April 17 had a different tag survival curve that is not represented by the tag life study. Thus, no attempt was made to adjust the estimated parameters from the mid-April release group for premature tag failure; the reported estimates represent both fish mortality and tag failure.

## Analysis of Surgeon Effects

Surgeon effects were analyzed in several ways. The simplest method used contingency tests of independence on the number of tag detections at key detection sites throughout the study area. Specifically, a lack of independence (i.e., heterogeneity) between the detections distribution and surgeon was tested using a chi-squared test ($\alpha = 0.05$; Sokal and Rohlf 1995). Detections from downstream sites in the Old River route were pooled within surgeon categories in order to achieve adequate cell counts for this test; detections from other sites that had sparse data from all surgeons were omitted. This meant that assessment of potential surgeon effects was limited to the upstream regions of the study area, in particular through the Navy Drive Bridge on the San Joaquin River, and through Old River South, the CVP trash racks, and the entrance to the Clifton Court Forebay (RGU) in the Old River route.

Lack of independence may be caused by differences in survival, route entrainment, or detection probabilities. A second method visually compared estimates across surgeons of cumulative survival throughout the region of the study area that had sufficient detections to estimate survival for all three surgeons, i.e., from Durham Ferry to Navy Drive Bridge or Rough and Ready Island, and Old River South. A third method used Analysis of Variance to test for a surgeon effect on individual reach survival estimates, and an F-test to test for a surgeon effect on cumulative survival throughout each major route (routes A and B). Finally, the nonparametric Kruskal-Wallis rank sum test (Sokal and Rohlf 1995: Ch. 13) was used to test for whether one or more surgeons performed consistently poorer than others, based on individual reach survival or transition probabilities through key reaches. In the event that survival was different for a particular surgeon, the model was refit to the pooled release groups without tags from the surgeon in question, and the differences in survival estimates due to the surgeon were examined. The reduced data set (without predator detections), pooled over release groups, was used for these analyses. No attempt was made to adjust the joint estimates of fish and tag survival for premature tag failure, because the high rate of premature tag failure from the first release group precluded estimating tag survival to arrival at individual detection sites. Instead, the estimates of joint fish-tag survival were used for this analysis, under the assumption that any surgeon effects were independent of the tag failure process among the different release groups. Because the most likely difference in the tag failure process across release groups was the tag programming error from the first release group, which occurred prior to exposure to the surgeons, this independence assumption was deemed reasonable.

## Analysis of Travel Time

Travel time was measured from release at Durham Ferry to each detection site. Travel time was also measured through each reach for tags detected at the beginning and end of the reach, and summarized across all tags with observations. Travel time between two sites was defined as the time delay between the last detection at the first site and the first detection at the second site. In cases where the tagged fish was observed to make multiple visits to a site, the final visit was used for travel time calculations. When possible, travel times were measured separately for different routes through the study area. The harmonic mean was used to summarize travel times.

## Route Selection Analysis

There was a physical barrier installed at the head of Old River in 2014 that effectively blocked most entry to Old River. Thus, no analysis of the factors affecting route selection (entrainment) at that river junction was performed. Furthermore, there were too few tags detected on any of the receivers near the Turner Cut junction to implement a route selection analysis for that junction in 2014. The location of the Stockton Waste Water Treatment plant near the receivers located at the Navy Drive Bridge and Rough and Ready Island raised questions about the assumption of common survival between the river junction and the receivers in both legs of the junction; that concern, combined with low detection counts at Rough and Ready Island (a total of 6), made it unsuitable to perform a route selection analysis at that junction, as well. Thus, no route selection analysis was performed for the 2014 study.

## Survival through Facilities

In similar studies of acoustic-tagged steelhead (Buchanan 2013, 2015), a supplemental analysis has been performed to estimate the probability of survival of tagged fish from the interior receivers at the water export facilities through salvage to release on the San Joaquin or Sacramento rivers. This analysis combined detections at Chipps Island with detections at Jersey Point and False River, and compared detection counts at those sites to counts of detections at the CVP holding tank and the interior receivers in the Clifton Court Forebay (site RGU). In 2014, there was only 1 tag detected (excluding predator-type detections) inside Clifton Court Forebay, and only 2 detected in the CVP holding tank. Although both tags detected in the CVP holding tank were later detected at either Chipps Island or Benicia Bridge, there were too few tags detected either at the facilities or at Chipps Island to complete an analysis of salvage through the facilities for Chinook Salmon in 2014.

## Update of 2010–2013 Multiyear Covariate Analysis

The 2014 data were prepared following the methods used in Buchanan (2017) for the 2010–2013 analysis, including formatting of tagging and detection data from tagged fish and covariates representing hydrological, environmental, and operational characteristics and fish size. Details on the data used from each study year are provided in Buchanan (2017). A limitation in the 2014 data is that flow and velocity measures were unavailable at the SJL gaging station in 2014, and flow data at the SJG gaging station (at Garwood Bridge) were missing during the 2014 study. Thus, those measures were omitted from the modeling.

The fit of the 2010–2013 models to the 2014 data was tested using the goodness-of-fit methods used in the 2010–2013 analysis (Buchanan 2017): the area under the curve (AUC) of the receiver operating characteristics curve was computed (Nam and D'Agostino 2002) and compared to the minimum "acceptable" value of 0.7 (Hosmer and Lemeshow 2000), and the predicted probability of survival was compared graphically to observed frequencies for grouped records. Goodness-of-fit was assessed for survival models using tags only from the late April and May release groups; the tag programming error for the mid-April release group precluded using those data to test the survival models. For the model for survival from Mossdale to the head of Old River, the existing models (2010–2013) used interaction effects between year and individual covariates that represent flow and temperature: Qvns.1mag, Qvns.1.cdec, and Tmsd (Buchanan 2017). Each of these year-specific models was compared to 2014 data for each of the four study years included in the model (2010 through 2013). Thus, the 2014 data were compared to the 2010 model of survival from Mossdale to the head of Old River, the 2011 model, the 2012 model, and the 2013 model separately. However, because the AUC is equivalent to the Mann-Whitney test statistic (Nam and D'Agostino 2002), the same AUC value will be computed for all year-specific models whose estimated slope coefficient (i.e., for covariate X) has the same sign (>0 or <0). It was not possible to assess the fit of the 2010–2013 route selection model to the 2014 data because the covariates used in the 2010–2013 model were not all available in 2014, in particular flow at SJL.

Route selection was modeled using a generalized linear model with binomial errors and a logit link using the probability of selecting the Old River route as the response (McCullagh and Nelder 1989). Only tagged fish detected on either the ORE or the SJL receivers were used in this analysis. Data from all such detected fish in 2014 were used, including the first release group, along with detections of fish from 2010–2013. A physical barrier was installed in both 2012 and 2014. The model with an effect of the physical barrier was essentially nested within the year effects model. The 2010–2013 analysis found an effect of year among the years without the physical barrier (2010, 2011, and 2013; Buchanan 2017), so a year effect was included for those years. The additional effect of year among the years with the physical barrier was tested using an F-test. If that test was significant, then the full year effects model was used for future model development, otherwise a model with a physical barrier effect and a year effect for 2010, 2011, and 2013 was used for future models. The effect of operating a non-physical barrier was included in 2010; see Buchanan (2017) for more details. Modeling used forward stepwise regression and the Bonferroni correction for multiple comparisons (Sokal and Rohlf 1995) to limit the familywise Type I error rate to $\alpha = 0.05$ within each step of the stepwise regression. Testing used analysis of deviance with F-tests for group-based covariates (e.g., day, night), and likelihood ratio tests ( $\chi^2$ tests) for individual-based covariates (Skalski et al. 1993).

Survival from Mossdale to the head of Old River receivers (SJL and ORE) was modeled using a known-fate model in a generalized linear model framework with binomial errors and logit link. Only tags from the second and third release groups in 2014 were used, in addition to tags from 2010–2013. The known-fate model assumes 100% detection probability at the detection sites in order to make inference to fish survival rather than to the joint probability of fish survival and detection. Analysis of deviance with an F-test was used to test for the effect of year over and above the effect of the physical barrier, and the resulting model was used as the basis for all future models. The effect of the operating non-physical barrier was included in 2010; see Buchanan (2017) for more details. Covariates used to model survival included measures of flow at Vernalis, water temperature at the MSD gaging station, fish length, barrier status, and time of day of departure from the Mossdale receivers (Buchanan 2017). Modeling followed the process used in Buchanan (2017) for 2010–2013, again using Bonferroni corrections to maintain a familywise Type I error rate of $\alpha = 0.05$ .

Survival from the SJL and ORE receivers (“head of Old River”) to Chipps Island was modeled using multinomial regression using a logit link; see Buchanan (2017) for more details on the model. Survival was modelled concurrently with detection at Chipps Island, and the dual array at Chipps Island allowed for inference to be made to survival separately from detection. Only tags from the second and third release groups from 2014 were used in this analysis, along with tags from 2010–2013. In 2014, none of the tags from the second and third release groups were detected at Chipps Island. Thus, it was not possible to include a year effect in the survival model. Instead, a route effects model was developed, in which tags were pooled across years within each route. Estimated tag survival from the head of Old River to Chipps Island could not be modeled using observed travel time from 2014, and so observed travel time, by route, from the other low flow years of 2012 and 2013 was used instead, together with the fitted tag survival model from the May 2014 tag life study. Detection probability at Chipps Island was measured as a function of total Delta outflow ("QOUT") at the time of estimated tag arrival at Chipps Island, using an expected travel time of 6 d (San Joaquin River route) or 3 d (Old River route) for tags that were detected at the SJL or ORE receivers but not at Chipps Island (Buchanan 2017). Modeling followed the process used in Buchanan (2017) for 2010–2013, again using Bonferroni corrections to maintain a familywise Type I error rate of $\alpha = 0.05$ . The effects of route and barrier were tested against a "maximal" model that fit a unique survival probability for each level of categorical variable that combined year, release group, route, and the status of the presence and/or non-physical barrier for 2010 and 2011, and release group and route with year pooled for 2012, 2013, and 2014 (omitting the first release group in 2014).

# Results

## Tagging

The QA/QC assessments were done once a day. When measurements were above or below the recommended criteria, they were identified (Table 8) and fixed as soon as possible.

## Transport

Water temperatures in the transport tanks rose less than 3$^{o}$ C during the transport trip to Durham Ferry (Appendix C, Table 2). Only one fish died during transport and none died just prior to release (Table 2).

## Dummy-tagged fish

None of the 133 dummy-tagged fish were found dead when evaluated after 48 h during the Chinook Salmon study in 2014 (Table 9). However, at assessment on two days (May 16 and May 17), only 14 of the 15 fish were found in the holding cans (Table 9). It is not clear what happened to the missing fish from the container on both of those days. All fish assessed were found swimming vigorously.

A total of 112 of the 133 dummy-tagged fish evaluated after 48 h had normal gill coloration, 132 of the 133 had normal eye quality, 125 of 133 had normal body coloration and only one fish had fin hemorrhaging (Table 9). The average scale loss ranged from 3.7 to 9.0% for the groups of fish assessed

(Table 9). Mean FL of fish in each group ranged from 93.3 to 99.0 mm (Table 9). After condition assessments, fish were necropsied to assess surgical technique. Composite scores for surgical technique ranged from 1.3 to 2.8 for the groups on individual assessment days (Table 10).

## Fish Health

Of the fish that were evaluated for fish health at the release sites by the CA-NV FHC, one fish died from the April 19 group, but no mortality occurred in the May 4 or May 19 release groups (Table D1). A penetrating abdominal wound (external abnormality) and degenerated intestine (internal abnormality) were noted on this single mortality. No significant scale loss or pale gills were noted in any of the sample groups. Overall, sutures were in good condition with minor inflammation noted in 3% (1/30) of fish sampled April 19, a loose suture noted in 3% (1/30) of fish sampled May 4, and minor hemorrhaging noted in 13% (4/30) of fish sampled May 19 (Appendix D)

No virus or other cytopathic effects were observed by cell culture over the 21 d incubation period. No obligate bacterial pathogens were detected, and other isolates were isolated in 3-24% of sample groups (Table D2). These other isolates were common fauna in the environment and fish's gastro-intestinal tracts (Aoki 1999) and were likely contaminates due to field sampling conditions. No significant abnormalities or signs of infection were detected in tissues from the fish examined. Gill ATPase activity levels (µmol ADP*mg protein-1*hr-1) ranged from 0.6 to 14.3. Two fish from the April 19 sample group were excluded from the analysis due to extremely high enzyme activity levels, which were likely errors in the protein measurement. The activity levels in the May 4 release group were lower than the April 19 and May 19 groups (Figure D3; $P < 0.001$, ANOVA).

No significant health issues were observed in release groups in 2014. The Chinook Salmon from MKRH used in the study did not have any signs of *T. bryosalmonae* infections common in the Merced River Hatchery Chinook Salmon during past years. The minor suture issues observed were observed in only a few individuals and did not impact overall health of the fish. Gill ATPase activity levels were stable or increasing over the study period, suggesting smolt development would not be a significant factor in fish performance. Gill ATPase activity in salmonids typically increases and peaks near the time of most active migratory behavior (Duston et al. 1991; Ewing et al. 2001; Wedemeyer 1996). Gill ATPase levels were similar in the first (April 19) and last (May 19) release groups, suggesting these fish were not yet past peak smolt development. The cause of the lower median gill ATPase levels observed in the second (May 4) Chinook Salmon release group was not apparent.

## Tag Retention Fish

One of the 75 fish in both the dummy-tagged and control groups died during the 33-d holding period: one dummy-tagged fish from Surgeon A and one control fish from Surgeon C. The mortalities were discarded before morphometric data were taken or necropsies were performed. These mortalities did not result in significant differences in survival between control and dummy-tagged fish. All remaining fish were swimming normally at the time of necropsy.

There was no significant difference between weights of released fish and weights of dummy-tagged fish used in the tag retention study (Mann-Whitney, P = 0.259): dummy-tagged fish weighed 10.8 ± 1.5 g (mean ± standard deviation; range, 8.3–15.4 g) and released fish weighed 11.1 ± 1.8 g (range, 7.7–20.2 g). The fork lengths of the two groups did differ significantly (Mann-Whitney, P < 0.001): 95 ± 4 mm (range, 87–102 mm) and 98 ± 5 mm (range, 80–119 mm) for dummy-tagged and released fish, respectively. The tag burdens of the two groups, however, were not significantly different (Kolmogorov-Smirnov, P = 0.051), with dummy-tagged fish displaying 3.96 ± 0.52% (range, 2.73–5.06%) tag burden and released fish exhibiting 3.82 ± 0.56% (range, 2.05–5.39%) tag burden. All dummy-tagged fish in the tag retention study retained their tags. It is highly unlikely that the released fish exhibited poorer survival as a result of tag burden than the dummy-tagged fish in this portion of the study. If survival was the same for the 1,918 study fish as it was for the dummy-tagged fish, no more than approximately 25 released fish died because of tag implantation or the overall health of the fish as part of this study.

There were no significant differences between control and dummy-tagged groups of each surgeon for final FL and scores for body color, fin hemorrhaging, eyes, and gill color. Fish of Surgeon C also did not exhibit any difference in scale loss between control and dummy-tagged fish, but those of Surgeons A and B did, with more scale loss for the dummy tagged fish. The percent scale loss of dummy-tagged fish also differed between the three surgeons: fish tagged by Surgeon A displayed more severe scale loss (11.8 ± 8.1%) after the 33 d holding period than those of Surgeon B (4.8 ± 7.4%) and Surgeon C (6.8 ± 4.1%). The scale loss of fish tagged by surgeons B and C did not differ. However, the scoring of this parameter is extremely subjective, and all surgeons scored fish on which they had performed the surgery, resulting in an inherent bias. Therefore, although statistically significant, these results likely do not represent a biological significance.

## Detections of Acoustic-Tagged Fish

Of the 1,918 acoustic-tagged fish released at Durham Ferry in 2014, 1,037 (54%) were detected on one or more receivers either upstream or downstream of the release site (Table 11), including any predator-type detections[2]. Total numbers of tags detected were comparable for the first (mid-April) and third (mid-May) release groups (380 vs. 361), and fewer tags were detected from the second (late-April/early-May) release group (296) (Table 11). A total of 1,010 tags (53%) were detected at least once downstream of the release site, and 497 (26%) were detected in the study area from Mossdale to Chipps Island (Table 11). More tags were detected upstream of the study area from the third release group (357) than from either the first (165) or second (183) release groups (Table 11). Forty-eight (48) tags were detected upstream of the release site; 21 of these were also detected downstream of the release site. All but four of the tags detected upstream of the release site came from the third release group (Table 12).

The majority of the tags detected downstream of the head of Old River were detected in the San Joaquin River route. Overall, there were 293 tags detected on one or more receivers in the San Joaquin River route (Table 11). In general, tag detections decreased within each migration route as distance from the release point increased. Of these 293 tags, 287 were detected on the receivers near Lathrop; 224 were detected on one or more receivers used in the predator removal study (all but one was detected on RS4); 62 were detected on one or more receivers near Stockton (SJG, SJNB, or RRI); 3 were detected on the receivers in the San Joaquin River near Turner Cut (MAC), 2 were detected in Turner Cut, and 1 was detected at Medford Island (Table 11). Although 293 tags were detected in the San Joaquin River downstream of the head of Old River, only 270 tags were assigned to the San Joaquin River route for the survival model (Table 11); the other 23 tags were subsequently observed in the Old River route or upstream of Old River, without later detections in the San Joaquin River route. The majority of the tags assigned to the San Joaquin River route came from the first release group (Table 11). None of the tags assigned to the San Joaquin River route were detected on the interior Delta receivers in Old and Middle rivers near Highway 4 (OR4, MR4), at the radial gates at the entrance to the Clifton Court Forebay (RGU, RGD), or the CVP (CVPtank). One tag assigned to the San Joaquin River route was subsequently detected at both the Old River receiver near the Old River mouth (OSJ, site B5) and Jersey Point; this tag was from the first release group, and was not detected at Chipps Island or any

[2] It was discovered in August 2017 that some HR detections had not been processed. Processing the data with these detections added detections to DFD and BCA (changes not shown in this report). Overall, there were 383 tags with different array code sequences caused by these additional detections. Of those 383 tags, only one tag had a different detection history at sites downstream of BCA on account of the additional HRR detections; that tag was from release group 1 (tag serial number 1181850). The estimate of survival from release at DF to MOS was unchanged, as were the estimates of survival from MOS to Chipps Island and from MOS to SJL/ORE. These minor changes have not been incorporated into the analyses or this report.

other site after its detection at Jersey Point (Table 12). No tags assigned to the San Joaquin River route from the second release group were observed downstream of the MacDonald Island (MAC) or Turner Cut (TCE/TCW) receivers; tags from the third release group were observed only as far downstream as the Stockton receivers near the Navy Bridge (SJNB) in the San Joaquin River route (Table 12).

Relatively few tags were detected in the Old River route (26), compared to the San Joaquin River route (293; Table 11). All tags detected in the Old River route were assigned to that route for survival analysis. All 26 tags detected in the Old River route were detected at the Old River East receivers near the head of Old River; 15 were subsequently detected on the Old River receivers near the head of Middle River (ORS); 6 were detected at the water export facilities or in West Canal; and 0 were detected at the receivers near Highway 4 (Table 12). No tags were detected on any of the Middle River receivers (Table 12). All tags detected at the facilities or West Canal entered Old River at its head, rather than coming from the lower reaches of the San Joaquin River route. Of the six tags detected at the water export facilities or West Canal, four were detected at the CVP trashracks, two at the CVP holding tank, two at the Clifton Court Forebay radial gates, and two at West Canal (Table 12). One of the tags detected at the radial gates was subsequently detected at the CVP trashracks, and so was assigned to the CVP route for analysis (Table 13). The West Canal detections were not used in the survival analysis.

Only one tag was detected at Chipps Island in 2014, and two tags were detected at Benicia Bridge. Both tags passed through the CVP holding tank prior to detection at Chipps Island or Benicia Bridge (Table 12). One tag was detected at Jersey Point (from the San Joaquin River route), and none were detected at False River, Threemile Slough, Montezuma Slough, or Spoonbill Slough (Table 12).

The predator filter used to distinguish between detections of juvenile Chinook Salmon and detections of predatory fish that had eaten the tagged salmon classified 275 of the 1,918 tags (14%) released (26% of those ever detected) as being detected in a predator at some point during the study (Table 12). The majority of the tags classified as predators were first so classified upstream of the study area or at Mossdale. Of the 497 tags detected in the study area (i.e., at Mossdale or points downstream), 146 tags (29%) were classified as being in a predator; all 146 were first classified as a predator within the study area, rather than upstream of the study area. A total of 130 tags were detected as a predator upstream of the study area (18% of the 705 tags detected in that region); all but one of them was first classified as a predator in that region (Table 14).

A total of 112 tags from the first release group (mid-April) were classified as in a predator at some point during the study; the majority (93) of these 112 tags were first classified as a predator within the study area (Mossdale or downstream) (Table 14). From the second release group (late April/early May), 61 tags were classified as in a predator during the study, of which slightly over half were first classified as a predator within the study area (Table 14). A total of 102 tags from the third release group (mid-May) were classified as a predator at some point during the study; unlike the previous release groups, the majority (83, or 81%) of these 102 were first classified as a predator upstream of the study area (Table 14).

Within the study area, the detection sites with the largest number of first-time predator classifications were the receivers just upstream of the head of Old River (B0, 30 of 407, 7%), Mossdale (A4, 21 of 496, 4%), and the first Predator Removal Study receiver (N1, 20 of 223, 9%)(Table 14). The Lathrop receivers (A5) also had a large number of first-time predator classifications (18 of 287, 6%). Collectively, the receivers in the San Joaquin and Old River near the head of Old River (sites A4, B0, A5, N1, B1) accounted for 93 (64%) of the 146 first-time predator classifications within the study area. Most of the other first-time predator classifications within the study area occurred at the other Predator Removal Study receivers (N2 –N7) and the Stockton receivers (A6, A7) (Table 14). MacDonald Island (A8), the CVP trashracks (E1), the radial gates (D1), West Canal (B3), and Chipps Island (G2) each had one tag first classified as in a predator at those sites (Table 14).

Considering all detection sites together, more of the 275 predator classifications were assigned upon tag departure than tag arrival at the site: 167 tags were first classified as in predators upon departure from a site, compared to 108 tags first classified as in predators upon arrival at a site (Table 14). Predator classifications on arrival were typically due to unexpected travel time, upstream transitions, or regional or local residence times, and were most common upstream of the study area (Table 14). Predator classifications on departure were typically due to long residence times, and were most prevalent upstream of the study area and in the San Joaquin River between Lathrop and Stockton (Table 14). Only detections classified as from predators on arrival were removed from the survival model, along with any detections subsequent to the first predator-type detection for a given tag.

When the detections classified as coming from predators were removed from the detection data, slightly fewer detections were available for survival analysis (Table 11–Table 13 vs. Table 15–Table 17). The largest changes in detection counts occurred at the Durham Ferry sites. Small changes in counts (≤5) were observed at the receivers near the head of Old River and down the San Joaquin River through MacDonald Island. With the predator-type detections removed, 982 of the 1,918 tags released (51%) were detected downstream of the release site (Table 15). There was no change in the total number of tags detected in the study area (497), although individual receiver sites had different counts with and without predator-type detections (Table 15, Table 12 vs. Table 16). There was no change in the total number of tags assigned to either route (San Joaquin River or Old River) for survival analysis. A total of 22 tags were detected upstream of the release site using only smolt-type detections (Table 16); of these, 8 were also detected downstream of the release site. Without the predator-type detections, one of the two tags detected at Benicia Bridge was omitted, because it was classified as being in a predator upon departure from Chipps Island (Table 16 and Table 17 vs. Table 11 and Table 12). All other changes in detection counts were restricted to the San Joaquin River receivers.

## Tag-Survival Model and Tag-Life Adjustments

The estimated mean time to tag failure from the first (April) tag life study, which used tags subject to the programming error and premature tag failure rate, was 12.4 d (SE = 4.7 d) (Figure 14). The complete set of detection data from the mid-April release group, which also used tags subject to the programming error and premature tag failure rate and including any detections that may have come from predators, contained many detections that occurred after the tags began dying (Figure 15). However, the accelerated failure rate of these tags and the difference between the activation dates of the released tags and the activation date of the tags in the tag life study made it inappropriate to adjust the estimated joint fish-tag survival and transition probability estimates by estimated tag survival for the mid-April release group (see *Analysis of Tag Failure*). Thus, no attempt was made to adjust the estimated parameters from the mid-April release group for premature tag failure; the reported estimates represent both fish mortality and tag failure. Without the detections classified as coming from predators, many of the late-arriving tag detections were omitted, but there remained detections occurring well after the tags began failing in the tag life study (Figure 16).

The estimated mean time to tag failure from the May tag-life studies (data pooled from all three studies) was 48.9 d (SE = 10.4 d) (Figure 17). The complete set of detection data, including any detections that may have come from predators, contained some detections that occurred after the tags began dying, although the majority of detections occurred before many tags had died (Figure 18). The sites with the latest detections were the San Joaquin River sites just downstream of the Durham Ferry release site, Banta Carbona, and Lathrop (Figure 18 and Figure 19). Some or all of these late-arriving detections may have come from predators. Without the detections classified as coming from predators, the majority of the late-arriving detections were omitted, and the latest detection was at Banta Carbona on day 16 (Figure 19).

Unlike for the mid-April release group and tag life study, the tags used in the late April and May releases and May tag life studies did not experience the tag programming error, and so it was appropriate to adjust the estimated survival estimates by estimate tag survival. Tag life corrections were made to survival estimates to account for the premature tag failure observed in the tag life studies. For the full data set that included any detections that may have come from predators, all of the estimates of reach tag survival were greater than or equal to 0.989, out of a possible range of 0–1. Without the detections that were classified as coming from predators, the reach tag survival estimates were all greater than 0.993. Thus, there was little effect of either premature tag failure or corrections for tag failure on the estimates of salmon reach survival for the second (late April/early May) and third (mid-May) release groups.

## Surgeon Effects

Fish in the release groups were evenly distributed across surgeon (Table 18). Additionally, for each surgeon, the number tagged was well-distributed across release group. A chi-squared test found no evidence of lack of independence of surgeon across release group ( $\chi^2$ = 0.0332, df = 4, P = 0.9999). The distribution of tags detected at various key detection sites was also well-distributed across surgeons and showed no evidence of a surgeon effect on survival, route entrainment, or detection probabilities at these sites ( $\chi^2$ = 13.048, df = 14, P = 0.5342; Table 19).

Estimates of cumulative survival throughout the San Joaquin River route to the Navy Drive Bridge/Rough and Ready Island receivers showed similar patterns of survival across all surgeons. Although Surgeon A had consistently lower point estimates of cumulative survival through the San Joaquin River route to Navy Drive Bridge/Rough and Ready Island, there was no significant difference in cumulative survival to any site in the San Joaquin River route (P ≥ 0.5415; Figure 20). Surgeon A had consistently lower point estimates to sites in the Old River route, as well (Figure 21), but there was no statistically significant difference in cumulative survival to any site in that route (P ≥ 0.5415). Analysis of variance found no significant effect of surgeon on individual reach survival estimates (P = 0.6945). Furthermore, despite the pattern of lower cumulative survival estimates for Surgeon A, rank tests found no evidence of consistent differences in reach survival estimates for fish from different surgeons (P = 0.9529).

## Survival and Route Entrainment Probabilities

Detection data of tagged Chinook Salmon in the lower San Joaquin River and interior Delta were sparse in 2014, and required simplification of the full two-part release-recapture model (Figure 10 and Figure 11) to the reduced full-Delta model shown in Figure 12, combined with the SD model shown in Figure 13. See *Survival Model Development* for more details.

### Release Group 1

For the mid-April release group, survival from the release site at Durham Ferry to the upstream boundary of the study area at Mossdale was estimated at $\hat{\phi}_{A1,A4}$ = 0.44 ($\widehat{SE}$ = 0.02) (Table 20). Most fish took the San Joaquin River route at the head of Old River ($\hat{\psi}_A$= 0.91; $\widehat{SE}$ = 0.02), and most also used the San Joaquin River around Rough and Ready Island ($\hat{\psi}_{A2}$ = 0.93; $\widehat{SE}$ = 0.04). Only two fish were detected at the receivers near the Turner Cut junction (MAC and TCE/TCW). Using detections from the other two release groups to help estimate detection probabilities at these sites, and survival and route selection probabilities ending in these sites (see *Parameter Estimation* for more details), the estimate of Southern Delta survival in the San Joaquin River route was $\hat{S}_{A(SD)}$= 0.01 ($\widehat{SE}$ = 0.01). No fish detected in the San Joaquin River route were also detected at either Chipps Island or Benicia Bridge ($\hat{S}_A$= 0) (Table 20).

Seventeen tags were observed entering Old River at the head ($\hat{\psi}_B$= 0.09; $\widehat{SE}$ = 0.02; Table 20). The transition probability from ORE (B1) to ORS (B2) was estimated at $\hat{\phi}_{B1,B2}$ = 0.53 ($\widehat{SE}$ = 0.12); no tags were detected at the nearby Middle River receivers (MRH = C1), so 0.53 is also the minimum estimate of survival between the head of Old River and the head of Middle River. Two tags were detected at the Central Valley Project trashrack (E1), one at the Clifton Court Forebay radial gates (D1), and none at Highway 4 (B4, C2); using detections from the other two release groups to estimate model parameters at the CVP and radial gates, the estimate of southern Delta survival in the Old River route was $\hat{S}_{B(SD)}$ = 0.12, $\widehat{SE}$ = 0.05). Total survival through the southern Delta was estimated at $\hat{S}_{Total(SD)}$ = 0.02 ($\widehat{SE}$ = 0.01;Table 20).

One tag detected in Old River at the head of Middle River (B2) was later detected at Chipps Island ( $\hat{S}_{B2,G2}$ = 0.11, $\widehat{SE}$ = 0.10), yielding the route-specific survival estimate in the Old River route of $\hat{S}_B$ = 0.04 ( $\widehat{SE}$ = 0.04). The single tag detected at Chipps Island passed through the CVP holding tank (E2) prior to detection at Chipps Island. Although also detected at Benicia Bridge, the predator filter classified it as in a predator upon arrival at Benicia Bridge after its detection at Chipps Island. Total Delta survival was estimated at $\hat{S}_{Total}$ = 0.004 ( $\widehat{SE}$ = 0.003) for the mid-April release group, whether predator-type detections were included or excluded (Table 20). There was no significant difference in survival estimates between the two routes (P = 0.1516).

All of the tags released in the first release group were subject to the programming error that caused premature tag failure (Figure 16), and it is likely that detection of some tags were missed as a consequence. No attempt was made to adjust for the high rate of tag failure for the first release group. This means that the available estimates of survival are more properly interpreted as the joint probability of survival of both fish and tag, and are thus minimal estimates of survival of the fish.

Only one tag was detected at Chipps Island (site G2) from the first (mid-April) release group, and only two tags at Rough and Ready Island (site R1) (Table 17). Although the estimates of detection probability were 1 (100%) at both these sites, the low number of detections introduces uncertainty into the detection probability estimate. Model fits using alternative detection probabilities at site R1 resulted in no difference in estimates of overall Delta survival ($S_{Total}$) or southern Delta survival ($S_{Total(SD)}$), but did affect estimates of $S_{A6}$ and $\psi_{A2}$ (e.g., $\hat{S}_{A6}$ = 0.78 and $\hat{\psi}_{A2}$ = 0.87 if $P_{R1}$ = 0.5, compared to 0.73 and 0.93 with $\hat{P}_{R1}$ = 1). The single detection at Chipps Island leaves considerable uncertainty about both the detection probability estimate at Chipps Island and the survival probability estimates to Chipps Island. If the detection probability at Chipps Island had been as low as 0.1, then survival from Mossdale to Chipps Island for fish that took the Old River route would have been estimated at 0.39 (yet with a high standard error of 0.38), whereas total Delta survival would be 0.04 ( $\widehat{SE}$ = 0.04). The small change in estimated Delta survival resulting from changes in detection probability at Chipps Island reflects the fact that most fish used the San Joaquin River route in 2014, and no fish detected in the San Joaquin River route were subsequently detected at Chipps Island. This means that accounting for a possibly low detection probability at Chipps Island does not automatically yield route-specific survival estimates > 0 for the San Joaquin River route. The data produced a survival estimate of 0.12 from Mossdale to the

Stockton Navy Bridge/Rough and Ready Island receivers (using the estimated detection probability of $\hat{P}_{R1}$= 1.0; using $P_{R1}$ = 0.1, estimated survival to A7/R1 was 0.19). Thus, we can conclude that survival to Chipps Island via the San Joaquin River route is ≤ 0.12, which means that the total survival combining the two routes would be ≤ 0.15, even if detection probability at Chipps Island were only 0.1. If detection probability at Rough and Ready Island (site R1) were also as low as 0.1, then we would be able to conclude only that total survival to Chipps Island is ≤ 0.20, in the unlikely event of no mortality between the Stockton Navy Bridge/Rough and Ready Island and Chipps Island.

Even combined with detections from the other release groups, there were only two tags detected at Turner Cut (TCE/TCW, F1) and one tag detected at the radial gates (RGU = D1, RGD = D2). Detection probabilities of 1 were estimated for these sites, but given the very few detections, there is considerable uncertainty in the detection probability estimates. If $P_{F1}$ were as low as 0.1, the southern Delta survival estimate in the San Joaquin River route would have been 0.07 ( $\widehat{SE}$ =0.03) for the mid-April release group, compared to the estimate of $\hat{S}_{A(SD)}$= 0.01 ( $\widehat{SE}$ = 0.01) using $\hat{P}_{F1}$ = 1. If $P_{D1}$ and $P_{D2}$ were both 0.1 instead of 1, the Southern Delta survival estimate in the Old River route would have been 0.21 ( $\widehat{SE}$ =0.13), instead of the actual estimate of $\hat{S}_{B(SD)}$= 0.12 ( $\widehat{SE}$ = 0.05) using $\hat{P}_{D1}$ = 1 and $\hat{P}_{D2}$ = 1. Using 0.1 for each of $P_{F1}$, $P_{D1}$, and $P_{D2}$, the total southern Delta survival would have been 0.08 ( $\widehat{SE}$ =0.04), compared to the estimate of $\hat{S}_{Total(SD)}$ = 0.02 ( $\widehat{SE}$ = 0.01) using $\hat{P}_{F1}$ = 1, $\hat{P}_{D1}$ = 1, and $\hat{P}_{D2}$ = 1.

## Release Group 2

Survival from the release site at Durham Ferry to Mossdale was considerably lower for the second (late-April/early-May) release group ( $\hat{\phi}_{A1,A4}$ = 0.26, $\widehat{SE}$ = 0.02; Table 20), compared to the first (mid-April) release group ( $\hat{\phi}_{A1,A4}$ = 0.44, $\widehat{SE}$ = 0.02). The large majority of fish used the San Joaquin River route at the head of Old River ( $\hat{\psi}_{A}$ = 0.91; $\widehat{SE}$ = 0.02). Of the 12 fish estimated to have reached the Navy Drive Bridge receivers (site A7) or the Burns Cutoff receivers (R1), most used the San Joaquin River route around Rough and Ready Island ( $\hat{\psi}_{A2}$ = 0.75; $\widehat{SE}$ = 0.12). Only 3 fish were detected at the receivers near the Turner Cut junction (MAC and TCE/TCW; $\hat{S}_{A(SD)}$ = 0.01, $\widehat{SE}$ < 0.01). Seven tags were detected in the Old River route at the ORE (B1) receivers ( $\hat{\psi}_B$ = 0.09; $\widehat{SE}$ = 0.03); the estimated transition probability from B1 to B2 (ORS) was $\hat{\phi}_{B1,B2}$ = 0.57 ($\widehat{SE}$ = 0.19). No tags were detected at the Middle River receivers at MRH (C1), so 0.57 is the minimum estimate of survival between the heads of Old and Middle rivers. A single tag was detected at the CVP, and no tags were detected at the Clifton Court Forebay radial gates or Highway 4 ($\hat{S}_{B(SD)}$ = 0.09, $\widehat{SE}$ = 0.04). Total survival through the southern Delta was estimated at $\hat{S}_{Total(SD)}$ = 0.01 ($\widehat{SE}$ = 0.01).

No tags from the second release group were detected at Chipps Island. However, one of the four tags detected at the Old River receiver at the head of Middle River (ORS, site B1) was later detected at Benicia Bridge ($\hat{\lambda}_{B2}$ = 0.25; $\widehat{SE}$ = 0.22). None of the tags detected in the San Joaquin River route were detected at Benicia Bridge ($\hat{\lambda}_{A7} = \hat{\lambda}_{R1}$ = 0). Because there were no detections at Chipps Island, it was not possible to estimate the detection probability at that site, and thus not possible to separately estimate survival to Chipps Island apart from survival to Benicia Bridge and detection there. The single tag detected at Benicia Bridge passed through the CVP holding tank, and neither it nor any other tags from this release group were detected at Chipps Island (G2), Montezuma Slough (T2), or Spoonbill Slough (T3). There were 75 steelhead tags detected at Chipps Island during the time when tags from the second Chinook Salmon release group were expected to have been passing that site (May 5–May 12, based on detections at upstream sites and at Benicia Bridge), and the estimated detection probability for steelhead tags from the late April steelhead release group was 0.98; although steelhead and salmon tags may have different detection probabilities, it appears that the Chipps Island receivers were functioning during this time period. Additionally, none of the tags in the second release group had the programming error that affected the tags in the first release group, and estimated tag survival through 20 d, which was longer than anticipated for salmon smolts to exit the Delta, was 0.96 (Figure 17). These observations suggest that the lack of Chinook Salmon detections at Chipps Island was caused by poor survival to that site, rather than malfunctioning receivers or tags. This possibility is consistent with the low estimated survival to the upstream boundary of the study area (MOS; $\hat{\phi}_{A1,A4}$ = 0.26) and through the southern Delta ($\hat{S}_{Total(SD)}$ = 0.01). Overall, there was very little difference in estimates that included predator-type detections (Table 21, Table E3).

The analysis of the sensitivity of the estimates of Southern Delta survival to the detection probability at Turner Cut (F1) and the radial gates (D1, D2) for the late April/early May release group found that if $P_{F1}$, $P_{D1}$, and $P_{D2}$ were each as low as 0.1, then the estimates of Southern Delta survival would be 0.04 ( $\hat{SE}$ = 0.02) in the San Joaquin River route, 0.17 ( $\hat{SE}$ = 0.11) in the Old River route, and 0.05 ( $\hat{SE}$ = 0.02) overall. This is compared to the actual estimates (using $\hat{P}_{F1}$ = 1, $\hat{P}_{D1}$ = 1, and $\hat{P}_{D2}$ = 1) of $\hat{S}_{A(SD)}$ = 0.01 ( $\hat{SE}$ < 0.01), $\hat{S}_{B(SD)}$ = 0.09 ( $\hat{SE}$ = 0.04), and $\hat{S}_{Total(SD)}$ = 0.01 ( $\hat{SE}$ = 0.01).

## Release Group 3

The mid-May release group had very low survival from Durham Ferry to Mossdale: $\hat{\phi}_{A1,A4}$ = 0.06 ( $\hat{SE}$ = 0.01), whether or not predator-type detections were excluded (Table 20, Table 21). Most fish used the San Joaquin River route at the head of Old River ( $\hat{\psi}_A$ = 0.94; $\hat{SE}$ = 0.04; Table 20). Only three tags were detected at the Navy Drive Bridge (A7), and two of them were classified as in predators; no tags were detected at the Rough and Ready Island site (R1), or at MacDonald Island or Turner Cut (Table 17). It was possible to estimate detection probabilities at those sites (and thus survival through the southern Delta) only by combining data from this release group with data from the previous two release groups (as done for releases 1 and 2). The estimated probability of survival through the southern Delta in the San Joaquin River route for this release group was $\hat{S}_{A(SD)}$ = 0.003 ( $\hat{SE}$ = 0.004). This is consistent with the very low survival estimate to Mossdale. Likewise, there were very sparse data in the Old River route. Only two tags were detected in the Old River route; both were detected at the Old River South receivers (B1), and one was detected at the CVP trashrack (E1); $\hat{S}_{B(SD)}$ = 0.26 ( $\hat{SE}$ = 0.10), using detections at the CVP and radial gates from all three release groups. No tags were detected at Chipps Island or Benicia Bridge ( $\hat{\lambda}_{A6} = \hat{\lambda}_{B1}$ = 0). Twelve steelhead tags were detected at Chipps Island during the time when the mid-May Chinook Salmon tags were expected to have been passing that site (May 18–25, 2014, based on upstream detections), indicating that the Chipps Island receivers were functional. Furthermore, the tags used in this release group of Chinook Salmon were not subject to the programming error from the first release group, and tag survival was modeled to be high through approximately day 40, well beyond when surviving Chinook Salmon were expected to have exited the Delta. The low number of detections of the mid-May Chinook Salmon tags at all sites from Mossdale downstream suggests that survival was in fact very low for this release group.

The very low detection count (2) at ORE (site B1) raises uncertainty in the estimation of the detection probability at that site ( $\hat{P}_{B1}$ = 1). The detection probability at that site influences the estimates of $\psi_{A1}$, $\psi_{B1}$, and $S_{A4}$. Using an assumed alternative detection probability of $P_{B1}$= 0.1 at ORE, the estimate of survival from Mossdale through the head of Old River increased to 1.23 ( $\widehat{SE}$ = 0.33) from the model estimate $\hat{S}_{A4}$= 0.78 ( $\widehat{SE}$ = 0.06), and the estimate of taking the Old River route at that junction increased to 0.41 ( $\widehat{SE}$ = 0.18) from the model estimate of $\hat{\psi}_{B1}$ = 0.06 ( $\widehat{SE}$ = 0.04). However, there was no effect on the estimate of survival to Chipps Island because there were no detections at Chipps Island for this release group. No other parameter estimates depended on the detection probability at ORE.

The analysis of the sensitivity of the estimates of southern Delta survival to the detection probability at Turner Cut (F1) and the radial gates (D1, D2) for the mid-May release group found that if $P_{F1}$, $P_{D1}$, and $P_{D2}$ were each as low as 0.1, then the estimates of southern Delta survival would be 0.02 ( $\widehat{SE}$ = 0.02) in the San Joaquin River route, 0.49 ( $\widehat{SE}$ = 0.28) in the Old River route, and 0.04 ( $\widehat{SE}$ = 0.03) overall. This is compared to the actual estimates (using $\hat{P}_{F1}$ = 1, $\hat{P}_{D1}$ = 1, and $\hat{P}_{D2}$ = 1) of $\hat{S}_{A(SD)}$ = 0.003 ( $\widehat{SE}$ =0.004), $\hat{S}_{B(SD)}$ = 0.26 ( $\widehat{SE}$ = 0.10), and $\hat{S}_{Total(SD)}$ = 0.02 ( $\widehat{SE}$ = 0.01).

## Pooled Release Groups

When data from the second and third (late April and early May) release groups were combined, it was not possible to estimate survival to Chipps Island because no tags were detected at that site. Estimated survival from Durham Ferry to Mossdale was low ( $\hat{\phi}_{A1,A4}$ = 0.16; $\widehat{SE}$ = 0.01;Table 19) with and without predator detections. Route selection into the San Joaquin River at the head of Old River was estimated at $\hat{\psi}_{A}$ = 0.92; $\widehat{SE}$ = 0.02; Table 20). The estimated overall probability of getting from Mossdale to Benicia Bridge and being detected there was $\hat{\lambda}_{A4}$ = 0.005 ( $\widehat{SE}$ = 0.005); however, because no detection probability could be estimated at Benicia Bridge, it was not possible to distinguish mortality from detection failure. Survival through the Southern Delta was estimated at 0.01 ( $\widehat{SE}$ < 0.01) for the

San Joaquin River route, 0.12 ( $\widehat{SE}$ = 0.05) for the Old River route, and 0.02 ( $\widehat{SE}$ = 0.01) for both routes combined (Table 20).

The analysis of the sensitivity of the estimates of southern Delta survival to the detection probability at Turner Cut (F1) and the radial gates (D1, D2) for the pooled late April and May release groups found that if $P_{F1}$, $P_{D1}$, and $P_{D2}$ were each as low as 0.1, then the estimates of southern Delta survival would be 0.03 ( $\widehat{SE}$ = 0.02) in the San Joaquin River route, 0.22 ( $\widehat{SE}$ = 0.13) in the Old River route, and 0.05 ( $\widehat{SE}$ = 0.02) overall. This is compared to the actual estimates (using $\hat{P}_{F1}$ = 1, $\hat{P}_{D1}$ = 1, and $\hat{P}_{D2}$ = 1) of $\hat{S}_{A(SD)}$ = 0.01 ( $\widehat{SE}$ < 0.01), $\hat{S}_{B(SD)}$ = 0.12 ( $\widehat{SE}$ = 0.05), and $\hat{S}_{Total(SD)}$ = 0.02 ( $\widehat{SE}$ = 0.01). Thus, uncertainty in the estimates of detection probability at Turner Cut and the radial gates does not translate into uncertainty in the magnitude of southern Delta survival; it is low regardless of the detection probabilities at those sites.

## Comparison between Release Groups

Parameter estimates were significantly (family-wise α = 0.10) higher for the second release group compared to the third release group for parameters $\phi_{A1,A4}$ and $S_{A2}$ (Table 22); the parameter estimate for $S_{A4}$ was significantly higher for the third release group compared to the second release group (Table 22). There was no significant difference between release groups in estimates of joint survival from Mossdale to Benicia Bridge and detection at Benicia Bridge ( $\lambda_{A4}$ ), despite the positive estimate of this parameter for the second release group and the estimate of 0 for the third release group (Table 22).

Water temperatures were greater for the third release group relative to the first and second releases (Figure 22). The third release group also had the lowest river flows during the migration period, with the first group having the highest flows, and the second group having intermediate flows (Figure 23). Exports were relatively low with the averages during the migration period of the first, second and third releases being 2,700 cfs, 1,830 cfs and 1,085 cfs, respectively (Figure 24).

## Travel Time

The single tag that was detected at Chipps Island came by way of the CVP holding tank, and was first detected at Chipps Island 6.04 d after release at Durham Ferry (Table 23a). This tag was from the first release group and so was subject to the programming error that resulted in premature tag failure (average tag life = 12.4 d, Figure 14). It is possible that other tagged Chinook Salmon also succeeded in reaching Chipps Island, but arrived there after their tags had failed.

Travel time from release to the Mossdale receivers averaged approximately 0.75 d ( $\widehat{SE} = 0.02$ d) for the mid-April release group, 0.73 d ( $\widehat{SE} = 0.02$ d) for the early May release group, and 1.17 d ( $\widehat{SE} =$ 0.07 d) for the mid-May release group (excluding predator-type detections; Table 23a). Average travel time to Garwood Bridge in the San Joaquin River was 2.24–2.58 d ( $\widehat{SE} \leq 0.27$) for the first two release groups, and 3.64 d ( $\widehat{SE} = 0.37$) for the third release. Average travel time to the Old River South receivers near the head of Middle River was approximately 1.5–1.8 d for each release group, although standard errors were relatively high ( $\widehat{SE} =$ 0.17–0.74 d; Table 23a). Despite the tag programming error present only for the first release of tags, the few tags observed at the CVP, Chipps Island, and/or Benicia Bridge had longer average travel time from the first release group than from the second or third release groups, which did not have the tag programming error (Table 23a). This suggests that there may have been additional tags from the first release group that arrived at these sites after their tags failed. When predator-type detections were included, average travel times tended to be slightly longer to receivers in the San Joaquin River upstream of Turner Cut, but there was little or no difference in travel time to most sites (Table 23b).

Average travel time through reaches for tags classified as being in juvenile Chinook Salmon ranged from 0.01 d (approximately 14 min) from the entrance channel receivers at the Clifton Court Forebay (RGU) to the interior forebay receivers (RGD), to 2.91 d for the single tag observed moving from the CVP holding tank to Chipps Island (MAE/MAW) (Table 24a); that single tag had the programming error that caused premature tag failure. The “reach” from the exterior to the interior radial gate receivers (RGU to RGD) was the shortest, so it is not surprising that it would have the shortest travel time, as well. Travel times from the San Joaquin River receiver near Lathrop (SJL) to Garwood Bridge (SJG) (approximately 18 rkm) averaged 1.0–1.3 d. Average travel time per release group from Old River South (ORS) to the Clifton Court Forebay or CVP trashracks (approximately 18.5 rkm) ranged from 1.1–1.6 d, but represented only 5 tags (Table 24a). Including the predator-type detections had little or no effect on average travel time through reaches, except for the reach from the Navy Drive Bridge to MacDonald Island (SJNB to MAC); only one tag was detected making that transition from the second release group, and excluding predator-type detections reduced the travel time from 35.6 d to 0.42 d (Table 24b vs. Table 24a).

## Multiyear Covariate Analysis

For 2014, 496 tags were detected at MOS (41 to 284 per release group) (Table 16). Median observed travel time from tag activation was similar for the first release group in 2014 to both SJL (4.0 d) and ORE (3.8 d), and the Kolmogorov-Smirnov test detected no difference in the travel time distributions to those two sites ($P = 0.5474$). Thus, the assumption of common tag survival to those two sites was reasonable, despite the tag programming error that resulted in premature tag failure; tags from all three release groups were used to update the existing model for route selection at the head of Old River. Tags from the second and third release groups were used to test and update models of survival from Mossdale to the head of Old River, and from the head of Old River receivers to Chipps Island. However, tags from the first release group were excluded from testing and updating the survival models because of the potential for the tag programming error to bias results. In particular, travel time from tag activation to Mossdale ranged from 2.8–9.2 d (median = 3.4 d) for the first release group in 2014. Because estimated tag survival had declined to approximately 74% for later-arriving fish at MOS from that release group, the estimated survival from MOS to the SJL and ORE receivers was confounded with tag failure.

## Route Selection Models

The probability of selecting the Old River route at the head of Old River was considerably lower in 2014 than in the years without a physical barrier (2010, 2011, 2013), but was generally higher than in 2012, when there was also a physical barrier installed (Figure 25). Both year and the physical barrier accounted for significant portions of the overall variability in route selection ($P < 0.0001$ for each covariate, Table 25). In 2010, the non-physical barrier also had a significant effect ($P = 0.0281$, Table 25). Among the years with the physical barrier (2012 and 2014), the year effect was not significant ($P = 0.4482$), so the covariate models used an underlying structure of year effects for years without a physical barrier (2010, 2011, and 2013), an effect of the operational non-physical barrier in 2010, and a physical barrier effect (essentially a common year effect) for 2012 and 2014:

$$\log\left(\frac{\psi_B}{1-\psi_B}\right) \sim Year_{noPB} + PB + NPBon_{Year=2010} + X_1 + X_2 + \cdots$$

for covariates $X_1$, $X_2$, etc.

With year and barrier effects accounted for, only the 15-min change in river stage at OH1 (delC.B.jx) and SJL (delC.A.jx) were significant at the familywise Type I error rate of $\alpha = 0.05$ (Table 26).

Measures of flow at SJL, including the flow proportion at SJL, were unavailable in 2014. When the 15-min change in river stage was accounted for, no other covariate had a significant effect at the familywise Type I error rate of $\alpha = 0.05$, although both velocity and river flow at OH1 had marginally significant effects at the testwise Type I error rate of $\alpha = 0.05$ (Table 27). Thus, the final model had structure:

$$\log\left(\frac{\psi_B}{1-\psi_B}\right) \sim Year_{noPB} + PB + NPBon_{Year=2010} + \Delta C.B.jx.$$

The area under the receiver operating characteristic (ROC) curve (AUC) was 0.74, which is considered "acceptable" (Hosmer and Lemeshow 2000). Comparison of the predicted probability and observed frequency of selecting the San Joaquin River route showed good fit of the model to the data (Figure 26).

The selected model included an effect of year among the years without a physical barrier (2010, 2011, and 2013), a physical barrier effect, an effect of the operating non-physical barrier in 2010, and an effect of the 15-min change in river stage at OH1 ($\Delta C_B$ = delC.B.jx), measured at the time of fish arrival at the head of Old River junction. The predicted probability of entering Old River was generally higher for higher changes in river stage, although the amount of expected change in route selection for a given change in $\Delta C_B$ depended on the year and barrier condition (Figure 27). In general, the rate of increase in the probability of entering Old River was highest for 2011 and lowest for the years with the physical barrier in place (2012 and 2014). This model suggests that as the 15-min change in river stage changes from negative to positive (i.e., as the tide changes from outgoing to incoming), the probability of entering Old River increases, and is highest when the tide is coming in the fastest (highest change in river stage) (Figure 27). Additionally, the physical barrier acted to reduce the probability of entering Old River ($P < 0.0001$), and the non-physical barrier had a marginally significant effect to reduce the probability of entering Old River ($P = 0.0531$) (Table 28).

## Survival: Mossdale to Head of Old River

Of the 3,071 tags observed at the MOS receivers in the San Joaquin River upstream of the head of Old River, 2,808 were subsequently detected at the SJL or ORE receivers just downstream of the head of Old River. Survival estimates through this reach ranged from 0.47 ($\widehat{SE} = 0.04$) for the second release in 2014, to 1.00 ($\widehat{SE}$ <0.01) for the first release in 2011 (Figure 28). There were a total of 263 degrees of freedom available for estimating and testing known-fate models. Considering data from 2010–2014, the estimates of detection probability ranged from 0.91 ( $\widehat{SE} = 0.02$) to 1.00 ( $\widehat{SE} = 0$) at SJL, and from 0.95 (

$\widehat{SE} = 0.03$) to 1.00 ( $\widehat{SE} = 0$) at ORE; thus, the known-fate model had the potential to underestimate survival slightly, mostly in 2011. In 2014 in particular, the estimated probability of detection at SJL (A5) was 0.99 (SE<0.01) for the second release group, and 1.0 ( $\widehat{SE} = 0$) for the third release group; at ORE (B1), the estimated detection probability was estimated at 1.0 ( $\widehat{SE} = 0$) for both release groups (Table E2). Thus, there was essentially no risk of confounding survival with imperfect detection for 2014.

Goodness-of-fit of the 2010–2013 models for survival from Mossdale to the head of Old River to the 2014 data was poor; AUC values ranged from 0.37 (all years for Tmsd model) to 0.59 (2011 for Qvns.1mag model) (Table 29). Thus, the existing models fit the 2014 data poorly. Comparison of observed versus predicted probability of survival from Mossdale to the head of Old River for 2014 using the 2010–2013 models also showed particularly poor fit (Figure 29). The tendency of the flow covariates used in these models to vary more between years than within one year accounts for some of the poor model fit, inasmuch as the 2010–2013 models were developed using only the flow values observed in each year. However, VNS flow values in 2014 were similar to the low end of the values observed for 2012 and 2013, and the models constructed for those years also showed particularly poor fit Figure 29). The 2014 study year had much lower survival in this reach than previous years, which also accounts for some of the poor model fit (Figure 28).

The model construction process was redone using data from both 2010–2013 and the second and third release groups from 2014. Both year and the presence of the physical barrier accounted for significant portions of the overall variability in detection at SJL and ORE, for fish that were previously detected at MOS ($P \leq 0.0001$ for each, Table 30). Within 2010, the non-physical barrier did not have a significant effect ($P = 0.3742$, Table 30). Among the years without the physical barrier (2010, 2011, and 2013), the year effect was not significant ($P = 0.4528$); among the years with the physical barrier (2012 and 2014), the year effect was significant ($P < 0.0001$). Because year had a significant effect even among those years with the physical barrier in place, a year effect was included in all future models.

When year effects were accounted for, the joint contributions of the main effect and interaction effect with year were significant for both measures of average San Joaquin River flow at VNS and for water temperature at the MSD station ($P < 0.0001$ for each, Table 31). The year interaction effect for each of these three covariates was also significant ($P < 0.0001$, Table 32). Of the three significant single-covariate models, the model that used the 1-day average magnitude of San Joaquin River flow at VNS measured from the time of tag release at Durham Ferry (Qvns.1mag) accounted for the most variability in the joint probability of survival and detection at SJL and ORE (AIC = 1471.31,Table 32).

When the Year × Qvns.1mag interaction effects were included in the model, only Qvns1.SD (1-d standard deviation of flow at VNS from release) had significant added effects (P = 0.0080) (Table 33). With both Qvns.1mag and Qvns1.SD in the model, no other covariates were significant (Table 34). Thus, the final model for the joint probability of survival from Mossdale to the head of Old River and detection at the SJL or ORE receivers (i.e., the known fate model for survival from Mossdale) used year, Qvns.1mag, and Qvns1.SD effects. The model structure was the following, where $\lambda$ is the joint probability of survival from Mossdale to the head of Old River and detection at either SJL or ORE:

Model M1.Smos: $$\log\left(\frac{\lambda}{1-\lambda}\right) - Year + Qvns.1mag + Qvns1.SD + Year \times Qvns.1mag$$

The effect of Qvns1.SD was only marginally significant at the familywise Type I error rate, and reflected the high survival of a small number of fish that had particularly high values of Qvns1.SD upon release in 2011. Without those fish, the effect of Qvns1.SD was no longer significant (P = 0.1518). Thus, the single-covariate model that included only Qvns.1mag was also presented:

Model M2.Smos: $$\log\left(\frac{\lambda}{1-\lambda}\right) - Year + Qvns.1mag + Year \times Qvns.1mag$$

The area under the receiver operating characteristic (ROC) curve (AUC) was greater than 0.78 for both models (Table 35). AUC values > 0.7 are considered “acceptable” (Hosmer and Lemeshow 2000), so both models perform adequately, according to the AUC measure. Comparison of the predicted joint probability of survival from Mossdale to the head of Old River and detection at SJL or ORE versus the observed frequencies of detection at SJL or ORE showed good agreement between the two models, especially for higher probabilities of entering Old River, but relatively poor performance for lower levels of Old River selection probabilities, in most cases (Figure 30). The AIC selected model M1.Smos, which used Qvns1.SD as well as Qvns.1mag (Table 35).

The model M1.Smos included effects of year, the 1-d average magnitude of San Joaquin River discharge at VNS (Qvns.1mag), and the 1-d standard deviation of VNS flow (Qvns1.SD). The 2014 study year had VNS flows that were similar to or lower than the flows in 2012 and 2013, and survival between Mossdale and the head of Old River was predicted to decline as VNS flow increased within that range of flows for 2014 (Figure 31, Table 36). The variability in VNS flows on the daily time scale, as measured by the 1-d standard deviation (Qvns1.SD), was similar in all years except 2011, which had very high flow variability for some observations in the first release group; survival between the Mossdale and the head of Old River was predicted to increase as the Qvns.1SD increased for all years (Figure 32, Table 36). There was little effect on the estimated regression coefficients relating to year and Qvns.1mag when Qvns1.SD was omitted from the model (Table 36).

## Survival: Head of Old River to Chipps Island

None of the 111 tags detected at SJL or ORE from the second and third releases in 2014 was detected at Chipps Island in 2014, although one tag from the first release group was detected at Chipps Island from the Old River route (Figure 33). The survival modeling to Chipps Island omitted the first release group in 2014 because of a high rate of premature tag failure. Out of the total of 3,016 tags detected at SJL or ORE in 2010–2014, 77 were detected at Chipps Island; thus, there were 77 degrees of freedom available for estimating and testing the survival and detection probability models. Figure 34 demonstrates that San Joaquin River discharge at VNS was considerably lower in 2014 than for most of the fish in other years, especially in 2010 and 2011, although it was comparable to the lowest flows observed in 2012 and 2013. Old River and Middle River flows (OMR[3]), also tended to be lower in 2014 than in most other years in the study, but were similar to 2013 (Figure 34).

The route effects model constructed for 2010–2013 in Buchanan (2017) used the 3-d RMS of Old River flow at Bacon Island (Qorb.ore.3rms). Because there were no tags detected at Chipps Island in 2014, the goodness-of-fit test using the area under the ROC curve could not be computed for the 2010–2013 model using 2014 data. Goodness-of-fit of the 2010–2013 model was assessed for 2014 data using a graphical comparison of observed vs predicted probabilities of the joint probability of survival and detection at Chipps Island, instead. Although there was no variability in the frequency of survival and detection at Chipps Island in 2014 (i.e., no tags were detected), giving the appearance of poor fit of the 2010–2013 model for 2014, the actual difference between the observed and predicted frequencies of survival and detection was low (0.0027 to 0.0210) (Figure 35). In comparison, the range of predicted probabilities of survival and detection from 2010 through 2013 was 0.0023 to 0.1357 for the 2010–2013 model.

[3] OMR = sum of Old River discharge at ORB (Old River at Bacon Island) gaging station and Middle River discharge at MID (Middle River) gaging station.

The 2010–2013 model was updated by fitting the model to data from 2010–2013 and the second and third release groups from 2014. The detection probability at Chipps Island was modeled first, followed by modeling of survival to Chipps Island.

### *Detection Probability at Chipps Island*

The detection probability model at the Chipps Island dual receiver-line array was modeled before survival. As in the case of the 2010–2013 model, when 2014 data were included, the difference in average detection probability at the two lines comprising the dual array was marginally significant ($\chi^2 = 3.85$, df = 1, P = 0.0496), and the common effect of total Delta outflow (QOUT) on detection probability at each line was significant ($\chi^2 = 4.92$, df = 1, P = 0.0266). However, there were too few degrees of freedom within the pattern of detections at the Chipps Island dual array to estimate both a unique average effect (intercept) and an effect of QOUT. Thus, the model selected by AIC was used for the detection probability model: common intercepts and common effect of QOUT (Table 37). The detection probability model accounted for 2 of the 77 total degrees of freedom.

### *Survival to Chipps Island*

The effect of migration route (San Joaquin River route [A] vs Old River route [B]) was estimated under the assumption that it was constant across all years, but it was not significant (P = 0.3853; Table 38). Neither the physical barrier (P = 0.9705) nor the operation of the non-physical barrier in 2010 (P = 0.6749) had an obvious effect on survival to Chipps Island (Table 38), although the physical barrier effect was masked by a common year effect of 2012 and 2014 relative to all other years. Despite the non-significance of the route effect, a route-based model was used as the foundation of further modeling efforts.

The combined main effect and interaction effects with migration route (A = San Joaquin River route, or B = Old River route) accounted for a significant amount of the variation in survival to Chipps Island for several measures of river flow in Old and Middle rivers and one measure of export rate: the 3-d RMS of river flow at ORB, MID, and OMR, and the 2-d average of export rate at CVP (Table 39). The average combined export rates at CVP and SWP, and the average export rate at SWP were nearly significant at the familywise Type I error rate of $\alpha = 0.05$ (Table 39). Measures of river flow at Brandt Bridge (Qbdt.sjl.2rms, Qbdt.sjl.2net), at OH1 in Old River (Qoh1.ore.3net, Qoh1.ore.3rms), and at Vernalis (Qvns.rel.4net) all had effects that were significant at the testwise Type 1 error rate of $\alpha = 0.01$ but not at the familywise error rate of $\alpha = 0.05$ (Table 39).

For each covariate that was found to be significant inTable 39, the interaction effects model with route was compared to the main effects route model, and the most parsimonious model was selected that accounted for variation in survival using route and the covariate in question (Table 40). For the 3-d RMS measures of flow at ORB and MID, and the combination OMR measure, the route-specific interaction effects were not significant ($P \geq 0.1737$). For the CVP exports measure, the route-specific interaction effect was significant ($P = 0.0009$). The model that accounted for the most variation in survival with the fewest parameters (based on AIC) was the main effects model using route and Qorb.ore.3rms, the 3-d RMS of Old River flow at ORB (Table 40).

When both the main effects of route and Qorb.ore.3rms were accounted for, the additional main and route interaction effects were significant at the testwise level of $\alpha = 0.05$ for some of the remaining covariates (i.e., both 2-d measures of river flow at Brandt Bridge, and all exports measures), but none was significant at the familywise level of $\alpha = 0.05$ (Table 41).

The best route effects model, based on likelihood ratio tests and AIC, included the main effects of route and Qorb.ore.3rms, the 3-d RMS of Old River flow at the ORB gaging station from the time of tag detection at SJL or ORE.  Results were presented for that model, as well as for competing models that used route-specific effects of CVPSWP.2, Qvns.rel.4net, Qoh1.ore.3rms, and IE.2, as in the multiyear analysis for 2010–2013 (Buchanan 2017). The model with CVP.2 was identified as having significant effects in the route model (Table 39), and the models using CVP.2, Qvns.rel.4net, and Qoh1.ore.3rms were each selected as the best of the exports, VNS flow, and OH1 flow models inTable 39. The CVPSWP.2 model is presented instead of the CVP.2 model to facilitate comparisons to the 2010–2013 results (Buchanan 2017). The IE.2 model was not significant in Table 39 even at the testwise level ($P = 0.3679$), but is presented as a water project operations model, along with the Qvns.rel.4net and CVPSWP.2 models.

There was very little difference in modeling results from the 2010–2013 models when the 2014 data were included. The route effects model that used the 3-d RMS of Old River flow at ORB predicted higher survival to Chipps Island in both routes for higher magnitude of discharge past ORB, survival was predicted to be higher in the Old River route than in the San Joaquin River route, and there was high uncertainty in the predictions (Figure 36 and Table 42). That model had reasonable goodness-of-fit: the AUC of the ROC curve was 0.74, which is adequate. Comparison of observed versus predicted probabilities of survival to Chipps Island showed reasonable fit for lower survival, but poorer fit for higher survival (Figure 37).

The exports model that used effects of migration route and the combined daily exports rate from CVP and SWP predicted a slight decrease in survival to Chipps Island in the San Joaquin River route for higher export levels, and a small increase in survival in the Old River route for higher export levels (Figure 38). Different combinations of CVP and SWP leading to the same combined exports level may result in different patterns, however. Survival in the San Joaquin River route was predicted to decline slightly for higher measures of average daily river flow at either VNS in the San Joaquin River (Figure 39) or OH1 in Old River (Figure 40), whereas survival in the Old River route was predicted to have a small increase for higher levels of flow (Figure 39, Figure 40). However, there was high uncertainty in the estimates, and the effects were statistically significant at the testwise level of $\alpha = 0.01$ ($P = 0.0074$ and $P = 0.0093$; Table 39), but not at the familywise level of $\alpha = 0.05$ used in model development. The water project operations model with both route and I:E predicted weak negative survival relationships in both the San Joaquin River route and the Old River route (Figure 41), although the relationships were not statistically significant ($P = 0.3679$; Table 39).

# Discussion

## Study in 2014

### Fish Health

The fish used in the 2014 salmon survival studies were from the Mokelumne River Hatchery (MKRH), in contrast to most of the past years when they were from Merced River Hatchery. In most years, Merced River Hatchery fish have PKD (SJRGA 2013), and it has been assumed that the PKD infections have likely contributed to the observed low survival through the Delta. Although the fish used in 2014 were from MKRH and did not have PKD, survival was still poor. Thus the poor survival observed in the San Joaquin Delta in 2014 was not from high infection rates of PKD, or other pathogens, but from some other non-health related cause. While warm temperatures would increase the incidence of PKD in Merced River Hatchery fish, the warm temperature may also have consequences for MKRH fish other than PKD or other pathogen infections.

### Tag Programming Error

The tag programming error present in the first (i.e., mid-April) release group resulted in a high rate of premature tag failure, and made it inappropriate to adjust the estimated joint probabilities of fish and tag survival for tag failure, as described in *Analysis of Tag Failure*. This means that the estimated survival transition probabilities for the first release group represent the joint probability of both the fish and the tag surviving (and the fish moving toward a particular detection site, in the case of the transition probabilities). The survival parameter estimates were more likely to have been affected by the premature tag failure than the route selection estimates, assuming that route selection was relatively constant throughout the migration period of the release group (i.e., installation of the barrier at the head of Old River did not occur during the period when the fish were migrating past that junction). The survival parameter estimates for total survival through the Delta ($S_{Total}$) were expected to be negatively biased by the premature tag failure for the mid-April release group; individual reach survival and transition probability estimates were also expected to be negatively biased, assuming a constant travel rate through the system. However, if some fish delayed migration in certain regions of the Delta or returned upstream after their tags failed, it is possible that some reach-specific survival estimates were positively biased.

### Sparse Data

Detections of tagged fish from the 2014 Chinook Salmon tagging study were sparse downstream of the head of Old River, especially in the Old River route, downstream of Stockton in the San Joaquin River, and at Jersey Point, Chipps Island, and Benicia Bridge. Detections were sparser for the later release groups. The lack of detections complicated analysis, in particular at sites where only few tags were detected. Detection probability estimates can often be calculated for dual arrays from only a few detections, but the estimates may be highly inaccurate. Estimates of southern Delta survival (i.e., to the Turner Cut junction in the San Joaquin River route, and to the water export facilities or Highway 4 in the Old River route) required pooled detections at those sites across all three release groups in order to fit the model. If survival in the downstream reaches of the southern Delta or detection probabilities at those sites varied considerably across release groups, then the estimates of southern Delta survival may be biased.

For the first release group, the detection probability at Chipps Island was estimated at 100% from the dual array at that site and from comparison with detections at Benicia Bridge, but this was based on only a single tag detected at either Chipps Island or Benicia Bridge. While the lack of detections may have been due to premature tag failure caused by the tag programming error, as well as potential low survival, producing a reliable estimate of the joint probability of fish and tag survival to Chipps Island depends on the detection probability estimate at Chipps Island, which was itself highly uncertain based on a single tag detection. Detection probability estimates were also uncertain at Rough and Ready Island, Turner Cut, and the radial gates. As detailed in the *Results* section for release group 1, detection probabilities as low as 0.1 at these sites would yield estimates as high as 0.19 to the Stockton Navy Bridge and Rough and Ready Island, 0.08 through the southern Delta, and 0.04 through the entire Delta. On the other hand, the "Rule of Threes" (Van Belle 2008:49) gives a 95% upper bound on the joint probability of fish and tag survival and detection at Chipps Island of 0.0165. Assuming an average travel time through the Delta of 6 d, or equivalently 9.2 d since tag activation (based on the single tag detected at Chipps Island and the average Delta travel time in 2012), the 95% upper bound on fish survival through the Delta was 0.022 assuming 100% detection probability at Chipps Island, and 0.222 if detection probability was as low as 0.1. Detection probability estimates at Chipps Island for steelhead released in 2014 ranged from 0.71 to 0.98, which suggests that the 95% upper bound of approximately 0.02 is more reliable for Chinook Salmon from the first release group, even accounting for detection probability and poor tag survival.

The second release group did not suffer from the tag programming error, but nevertheless, only one tag was detected at Benicia Bridge, and no tags were detected at Chipps Island. Thus, we can conclude that the detection probability at Chipps Island was < 100%, but we have no information on what it may have been. Steelhead tags detected at Chipps Island in a similar time period had an estimated detection probability of 0.98, which indicates that the Chipps Island receivers were functioning within several days or weeks of when the Chinook Salmon tags were expected to have been passing. Even accounting for possibly very low detection probabilities at Turner Cut and the radial gates, total survival through the southern Delta was < 0.05, which indicates even lower survival through the entire Delta. The 95% upper bound on total Delta survival was 0.017 assuming 100% detection at Chipps Island, or 0.034 if detection probability was only 50% at Chipps Island; considering the low survival through the southern Delta and the high detection probability of steelhead tags at Chipps Island, it is safe to conclude that Delta survival for Chinook Salmon from the second release group was very low.

The third release group had even fewer detections downstream of Mossdale than the previous two release groups. The 95% upper bound on total Delta survival was approximately 0.07; this was higher than that estimated for the earlier release groups because the effective sample size for estimating Delta survival was considerably lower for the third release group (only 41 tags at Mossdale, compared to 170–284 from the earlier release groups), resulting in less information on Delta survival for this release group (i.e., low precision). However, southern Delta survival was estimated at only 0.02 for the third release group using the estimated detection probabilities, and at only 0.04 if detection probabilities were as low as 0.1 at Turner Cut and the radial gates; thus, it is reasonable to conclude that total Delta survival was also < 0.04.

### Survival between Lathrop and Garwood Bridge

For all three release groups, survival was low in the San Joaquin River between the Lathrop and Garwood Bridge receivers: $\hat{S}_{A5}$ = 0.24, 0.20, and 0.10 for release groups 1, 2, and 3, respectively (Table E2). These estimates are considerably lower than they were in 2012 (population estimate = 0.69: Buchanan et al. 2015) or 2013 (population estimate = 0.36: Buchanan et al. 2016). This reach was part of the 2014 NMFS predator removal study, and there were additional receivers located throughout this reach for that study (RS4–RS10; Table 5). A total of 61 Chinook Salmon tags were first classified as being in a predator at these sites, which amounted to 22% of the total number of tags classified as in predators during the salmon tagging study (Table 14). The spatial imprecision of the predator filter means that there is uncertainty in exactly where the predation event happened, and makes it inadvisable to estimate survival in each of the subreaches between adjacent removal study receivers. However, subdividing the entire reach from Lathrop to Garwood Bridge into two reaches is reasonable because it overlooks most of the spatial uncertainties in mortality. A Cormack-Jolly-Seber model was fit to detections from Lathrop, RS7 (=model site N4), and Garwood Bridge for each release group, using adjustments for tag failure for releases 2 and 3. Estimates of survival from SJL to RS7 ranged from 0.35 ($\widehat{SE}$ = 0.06) for the second release group to 0.42 ($\widehat{SE}$ = 0.04) for the first release group. Between RS7 and SJG, survival was higher for the first two release groups (0.56 to 0.58, with $\widehat{SE} \leq$ 0.10), but lower for the third release group (0.25, $\widehat{SE}$ = 0.12). Although a large number of tags were first classified as predators within these two subreaches, the subreach survival estimates were similar with and without predator-type detections; the exception was for the third release group in the downstream subreach, for which the survival estimate using predator-type detections was nearly twice that of the estimate that excluded predator-type detections (Table 43). For the first two release groups, mortality appeared greater in the upstream subreach (SJL to RS7), while for the third release group, mortality was considerably higher in the downstream subreach (RS7 to SJG) (Table 43).

## Project Objectives

The 2014 study focused on estimating juvenile Chinook Salmon survival through the San Joaquin River and Delta (and routes contained within) in April and May of 2014. The main goal, in combination with other years of data, was to relate survival to water temperature, river flow, CVP and SWP exports, and the absence or presence of a physical barrier at the head of Old River. This goal and the six specific objectives (a–f) of the project were mostly unmet in 2014.

Although fish used in 2014 were generally healthy and did not have PKD, premature tag failure of tags used in the first release group and poor survival for the second and third release groups limited our ability to estimate survival through the Delta, from Durham Ferry and Mossdale to Jersey Point and Chipps Island (Objective a), because so few fish were detected at many of the receivers. It may have been possible that survival for the first release group was greater than has been estimated due to the premature tag failure rate due to the defective tags. So few fish (2 for the first release group and 3 from the second release group) were detected at the receivers near the Turner Cut junction (MAC and TCE/TCW) that we were unable to identify the proportion of fish entering Turner Cut because too few fish survived to the junction (Objective b). Although we were able to estimate the proportion of fish that went into Old River (Table 20; also Objective b), we did not have enough detections downstream of the HORB junction to estimate survival in both of the routes for release groups 2 and 3 (Objective c). For release group 1, where estimates were made with tagged fish that had the premature tag failures, there was no difference in estimates of joint fish-tag survival between the two routes through the Delta (Table 20; Objective c). Comparisons in reach specific mortality (Objective d), and in survival between releases and between years (Objective e) were limited due to the sparse data. Survival could be estimated in only a few of the reaches in 2014 for comparison to past years and for contribution to the models for assessing the role of flow, water temperature, exports and a HORB (Objective f) on survival through the Delta.

## Update of Multiyear Model

The existing multiyear models of survival from Mossdale to the head of Old River and on to Chipps Island (Buchanan 2017) were changed little by including the 2014 data. Whether this was due to similarity in performance between 2014 and the other low flow years of 2012 and 2013, or rather to the sparse data available in 2014, was uncertain. Survival to Mossdale was low compared to previous years (0.06 and 0.26 for the latter two release groups in 2014, compared to 0.32 to 1.00 in 2010–2013), resulting in few observations to use in the multiyear model compared to previous years: 211 tags available for modeling survival from Mossdale to the head of Old River (i.e., the SJL and ORE receivers) in 2014, and 111 tags available for modeling survival from the SJL and ORE receivers to Chipps Island in 2014. The necessity of omitting the tags from the first release group in 2014 because of the high rate of premature tag failure contributed to the lack of influence from 2014 in the multiyear modeling results.

Nevertheless, when 2014 data were included in modeling survival from Mossdale to the head of Old River, both year-specific effects of the 1-d average of San Joaquin River flow at VNS and effects of the 1-d standard deviation of VNS flow were found to be significant (Figure 31 and Figure 32), whereas the 1-d standard deviation of VNS flow was not significant without 2014 (Buchanan 2017). However, the effect of the VNS flow standard deviation (i.e., a measure of short-term variability in Delta inflow from the San Joaquin River) was only marginally significant (Table 33), and the predicted survival effect had high uncertainty in some years (Figure 32). Modeling results for survival from the head of Old River receivers (SJL and ORE) to Chipps Island including 2014 were nearly identical to those without 2014 (compare Figure 36 and Figure 38–Figure 41 to Buchanan [2017]: Figures 67–71).

A further limitation in modeling survival and route selection was the lack of river discharge data at the SJL and SJG (=STK) stations in the San Joaquin River in 2014. In the absence of those data, the variable identified as important in the route selection model at the head of Old River, apart from year and the presence of a rock barrier, was the 15-min change in river stage at the OH1 gaging station in Old River near its distributary point with the San Joaquin River (Figure 27), rather than flow at SJL and river stage at either OH1 or SJL as identified for the 2010–2013 analysis (Buchanan 2017: Figures 34–35). The 15-min change in river stage at OH1 also had a significant effect in the 2010–2013 analysis, although less so than flow at SJL (Buchanan 2017: Table 7), so it is likely that the difference in modeling results when 2014 was included reflects the absence of flow data at SJL in 2014 rather than a change in mechanism. The small number of tags available for analysis of route selection in 2014 (N = 267) compared to the number of tags from the other years (N = 2,890) lends credence to this possibility.

Analyses of acoustic tag study results between 2010 and 2014 suggest survival increases between Mossdale and the Old River junction (HOR) with higher San Joaquin River flow at VNS and higher standard deviation of VNS flow (Figure 31 and Figure 32), respectively. The probability of staying in the San Joaquin River at the Old River junction also increased with increased flows at Vernalis (Figure 27). These results are consistent with our conceptual model.

Survival between Mossdale and the Old River junction decreased at higher water temperatures when year was accounted for (Table 31), but that effect disappeared when both year and Vernalis flow were accounted for (Table 33). Temperature and flow are negatively correlated, so it is not clear if the mechanism is actually flow, temperature, both, or some other factor.

The modeling results predicted survival to be higher between the HOR and Chipps Island in both the Old River and San Joaquin River routes with a higher 3-d RMS of Old River flow at Bacon Island (Figure 36). Survival was predicted to be higher in the Old River route than in the San Joaquin River route, but there was high uncertainty in the predictions (Figure 36). This suggests the amount of flow in Old River at Bacon Island is important to survival from the HOR to Chipps Island regardless of its flow direction and may be indicative of the influence of daily variation in tide and exports on flow in these routes. The flow in the Old River at Bacon Island is influenced by the CVP pumping rates and the operation of the gates at Clifton Court Forebay. Inflow and tides, as well as exports, affect the direction (upstream or downstream) of flows in Old River downstream of the facilities (e.g., Bacon Island and further downstream), complicating the understanding of how the RMS of flow in Old River at Bacon Island affects survival through the Delta.

Our conceptual model hypothesizes that once fish enter the interior Delta or into the strongly tidally influenced lower San Joaquin River, residence times increase and survival decreases. While results from the north Delta found travel time was inversely related to river inflow in all reaches, including the downstream reaches of the Delta, survival was not related to travel time in the downstream tidal reach of the Sacramento River (Perry et al. 2018). However, at low inflows, median travel times for tagged salmon migrating through the tidal reaches were considerably longer than for other reaches in the Sacramento River Delta (Perry et al. 2018), suggesting the fish are slowing down once they reach the tidal reaches, but it is not necessarily affecting the survival in tidal reaches of the lower Sacramento River. Perry et al. (2018) found that median travel times for the interior Delta reach (reach 8) were about three times greater than those in the tidal reach of the lower Sacramento River at low flows, demonstrating that the route through the interior Delta was taking quite a bit longer than the alternate route through the tidal reaches of the lower Sacramento River. Survival through the interior Delta is lower than it is for fish that stay on the lower Sacramento River (Brandes and McLain 2001; Newman 2008; Newman and Brandes 2010; Perry et al. 2010) and the increased time it takes to migrate through it could be one of the reasons why.

Travel time in the south Delta and its effect on survival is more complicated than that in the north Delta. In the interior Delta, we hypothesize that increasing exports would increase or reduce travel times in the Delta depending on the route the south Delta fish take. If fish are routed to the facilities from the San Joaquin River through Turner and Columbia cuts, their travel times will increase compared to if they were routed to the facilities more directly through upper Old River. Thus, we would predict that increased exports would lower survival in the San Joaquin River route due to an increase in travel time, and increase survival in the Old River route due to a shorter travel time. The multiyear exports modeling seems to support this hypothesis with the combined daily exports rate from CVP and SWP predicting a slight decrease in survival to Chipps Island in the San Joaquin River route for higher export levels, and a small increase in survival in the Old River route for higher export levels (Figure 38).

Whether higher exports increase or decrease survival also depends on the success of salvaging entrained fish once they arrive at the fish facilities. In 2014, there were too few tags detected either at the facilities or at Chipps Island to complete an analysis of salvage through the facilities for Chinook Salmon in 2014.

We have not obtained enough data in the lower reaches of the Delta from the south Delta studies to determine if survival in the predominately tidal areas is related to travel time. Survival has been so poor through the south Delta that very few smolts have survived to the lower reaches of the Delta of which to compare travel times. Starting in 2015, releases for the south Delta program were made at Durham Ferry as well as downstream (Medford Island in 2015, and near Stockton in 2016 and 2017) which could provide better information on survival in downstream reaches. Hopefully these data will provide some insights in the future on survival in the lower reaches of the Delta and its potential relationship to travel time and other factors.

In the north Delta, increased flows are associated with increased survival in the transitional reaches of the Delta (i.e., reaches that vary between unidirectional and bi-directional flow), and also with changes in route selection probabilities, such that the increases in flow result in increases in survival through the whole Delta (from Freeport to Chipps Island). Flow, velocity, change in stage, and flow proportion also are associated with changes in the route selection probabilities at the head of Old River when the HORB is not installed (Buchanan 2017), such that increases in Vernalis flows are observed with higher proportions of fish staying in the San Joaquin River. This pattern appears consistent between the north and south Delta. But because route survival in the San Joaquin River and in the Old River has been equally low and not significantly different in most cases, it has not improved overall survival through the Delta for tagged smolts migrating between Mossdale and Chipps Island. It is not clear whether the same mechanism for route selection is true at Turner Cut or other downstream junctions in the south Delta because not enough data have been collected to assess them.

If mechanisms were similar between the north and south Delta we would expect survival to be related to flow in the “transitional reaches” of the south Delta. The sparse data in many cases do not allow us to break down the routes into smaller reaches and determine the importance of flow or other covariates in the smaller reaches. Additionally, depending on the inflow and the strength of the tides, these transitional reaches can change between years and between releases.

In this report, we have broken up the south Delta into essentially two sequential reaches: Mossdale to the HOR and between the HOR and Chipps Island. Within the HOR and Chipps Island reach, there are two routes: the San Joaquin route and the Old River route. The highly variable environmental conditions in these two routes may require looking at individual subroutes or smaller reaches to fully address the complex survival-flow relationship, with both more years of spatially detailed data and consistently high sample sizes within each year.

## Acknowledgments

Funding for the project came from the California Department of Water Resources and the Central Valley Project Ipmrovement Act’s Comprehensive Assessment and Monitoring Program. Several individuals from a variety of agencies made this project possible. Those agencies and individuals who participated in the tagging and release components of the project were—USFWS: Krista Blandin, Eric Belt, Jeffrey Cullen, Dustin Dinh, David Dominguez, Kyle Fronte, Christopher Hart, Carlie Jackson, Jerrica Lewis, Tim Matt, Louanne McMartin, Greg Nelson, Randall Raeder, Elizabeth Reynolds, Lori Smith, Ronald Smith, Kandi Vargas; National Marine Fisheries Service: Brandon Lehman; USBR: Raymond Bark. USGS provided training for the surgeons (Theresa [Marty] Liedtke), deployed and maintained the receivers (Chris Vallee, Jon Burae, and Norbert VandenBranden) and preprocessed the data (Mike Simpson).

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## Figures


**Figure 1: Tag being activated in VEMCO tag activator. Photo Credit: Jake Osborne/USFWS**

**Figure 2: Personnel from USFWS (left) and NMFS (right) tagging Chinook Salmon as part of the 2014 Salmon Survial Study. Photo credit: USFWS**

**Figure 3: Recovery buckets with hydrophones (left) and VR100 mobile receivers (right). Note timers on bucket lids to assure at least a 10 min recovery period. Photo credit: USFWS**


**Figure 4: Two of the smaller transport tanks on a transport truck for transporting juvenile salmon in 2014. Photo credit: USFWS**

**Figure 5: Perforated buckets were unloaded from the transport truck, placed into “sleeves” containing river water held in a pick-up truck parked parallel to the transport truck (left), and then driven to the water’s edge and unloaded (right). Photo credit: Pat Brandes/USFWS**

**Figure 6: Perforated buckets inside “sleeves” on the bank of the river (left) waiting to be moved into perforated holding cans in the river (right). Photo credit: Pat Brandes/USFWS**

**Figure 7: Transporting tagged juvenile salmon in holding cans within a sleeve to the release site at Durham Ferry in 2014. Photo credit: Pat Brandes/USFWS**

**Figure 8: Processing dummy-tagged fish after they have been held for 48 h and taken halfway out to the release site and back. Photo credit: Pat Brandes/USFWS**

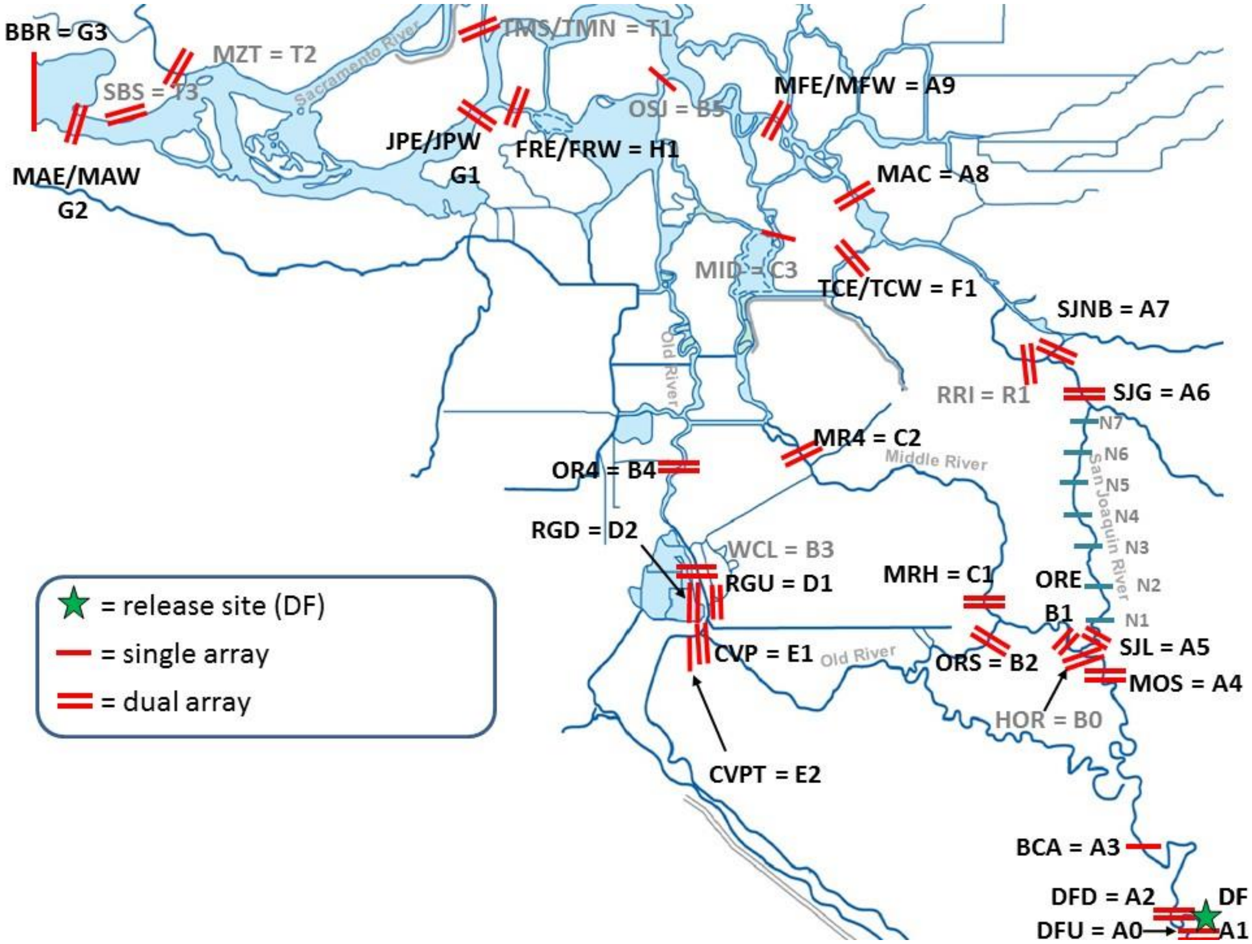


**Figure 9. Locations of acoustic receivers and the release site used in the 2014 Chinook Salmon tagging study, with site code names (3- or 4-letter code) and model code (letter and number string). Site A1 is the release site at Durham Ferry.**

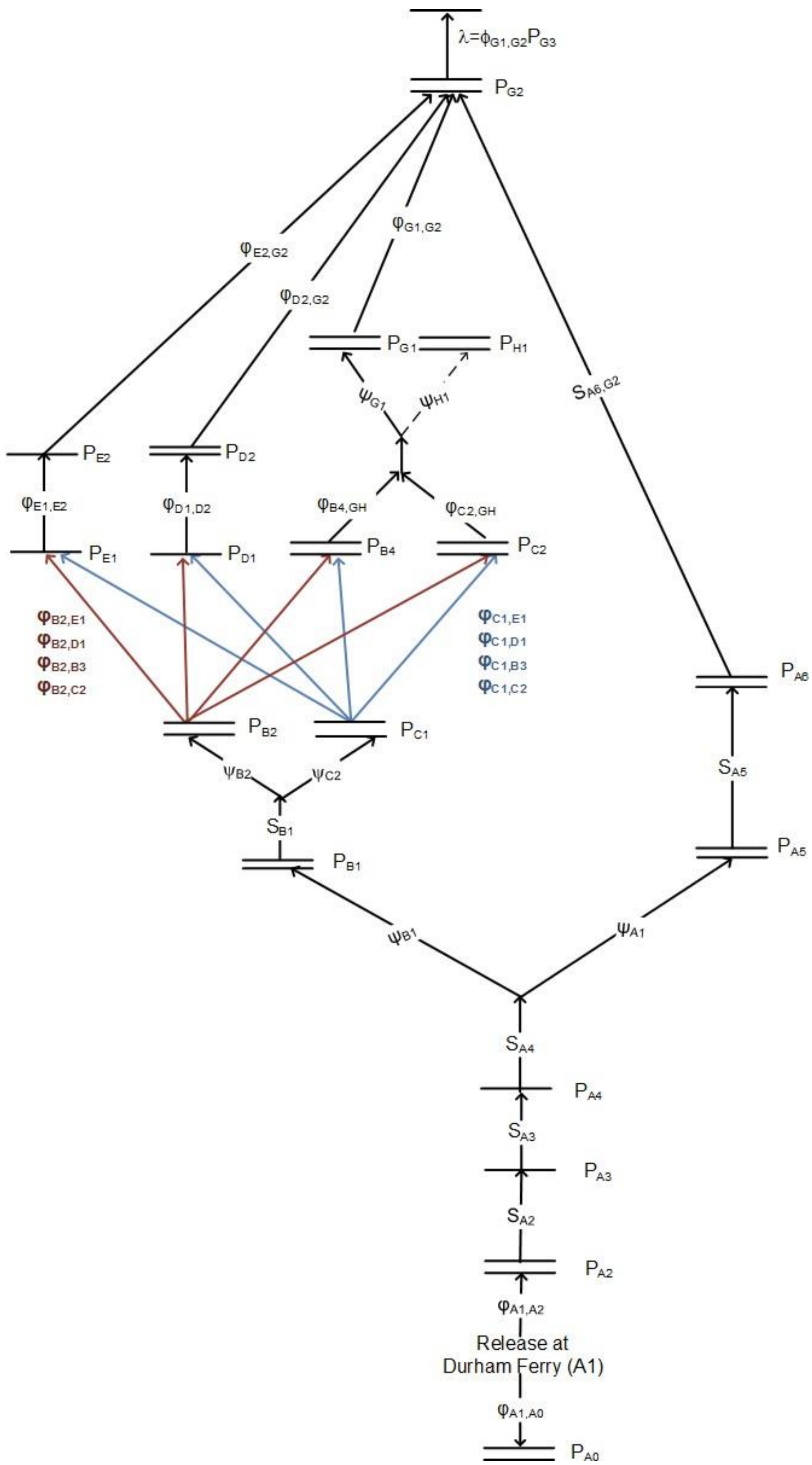


**Figure 10. Schematic of full 2014 release-recapture Submodel I with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 9. Migration pathways to sites B4 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.**

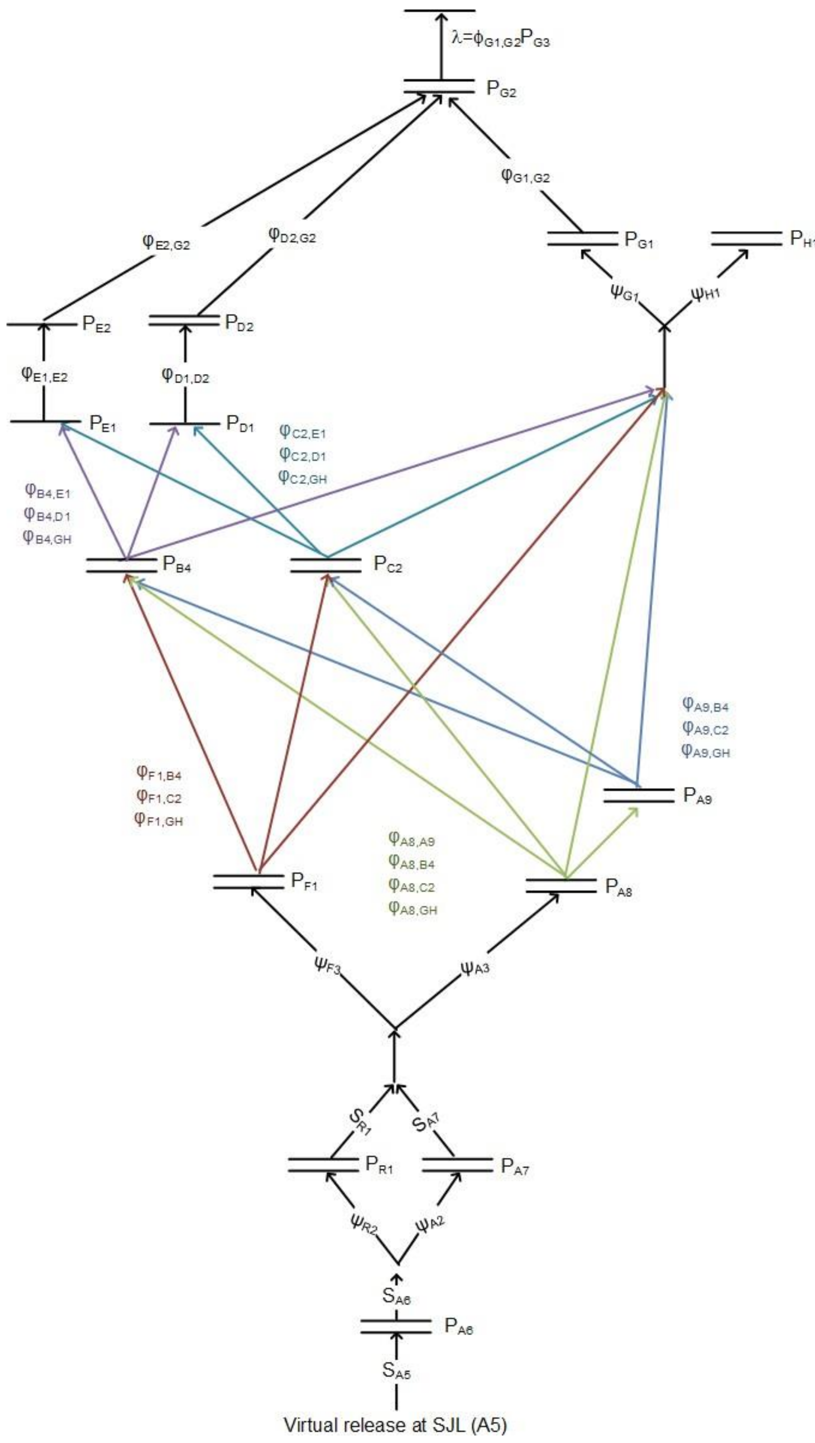


**Figure 11. Schematic of full 2014 release-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 9. Migration pathways to sites B4 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.**

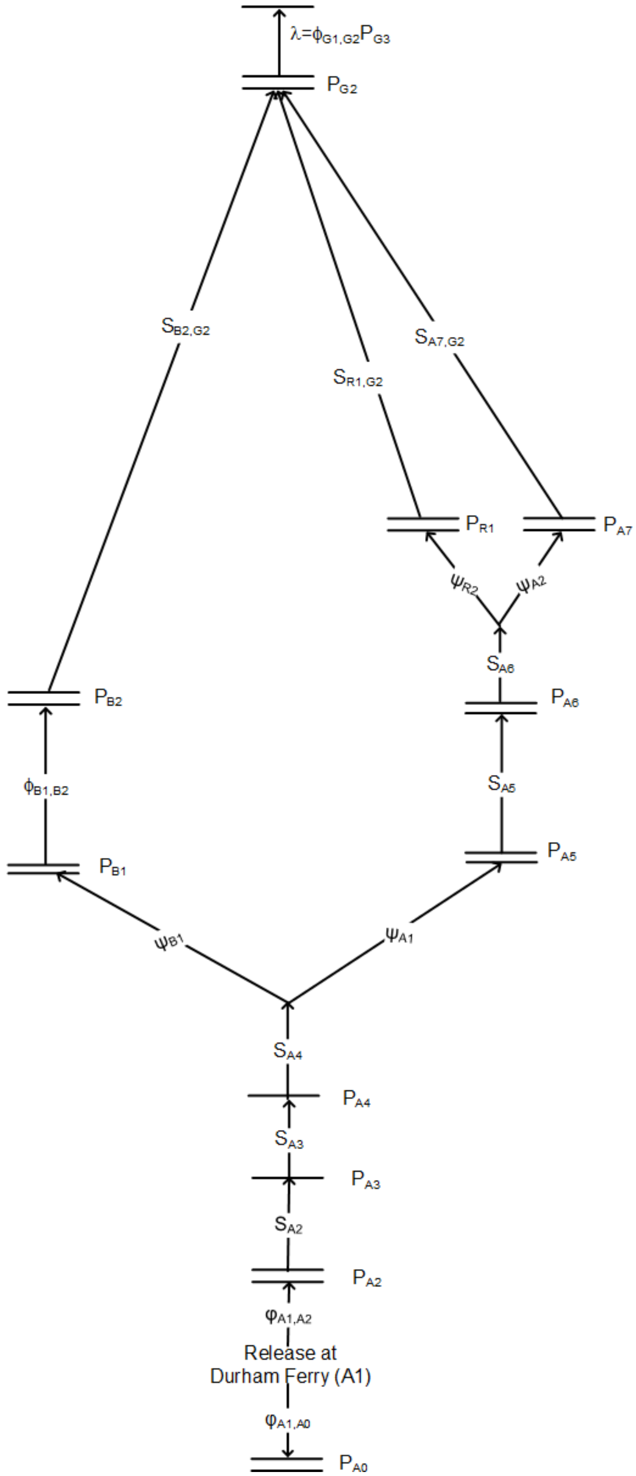


**Figure 12. Schematic of simplified 2014 release-recapture model used in analysis, with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 9.**

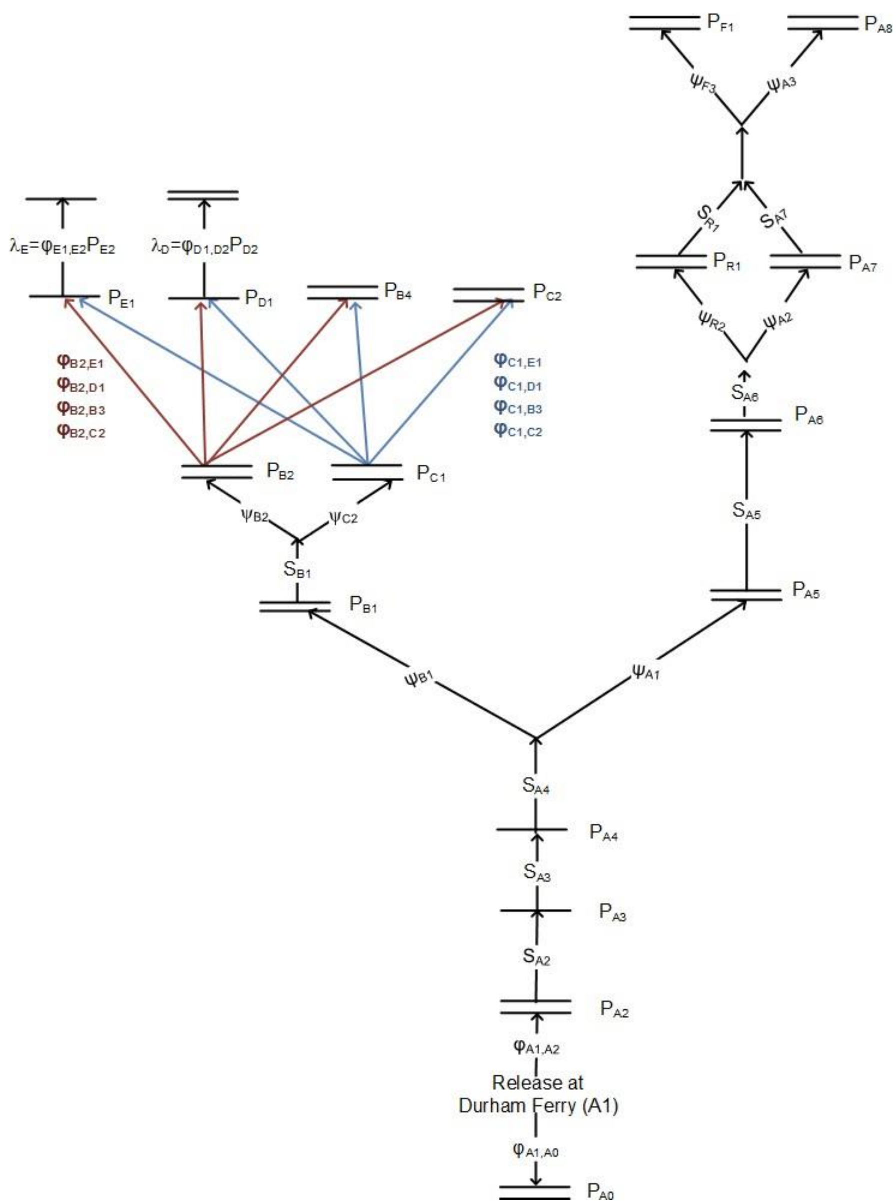


**Figure 13. Schematic of Southern Delta release-recapture with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 9. Migration pathways to sites B4 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.**

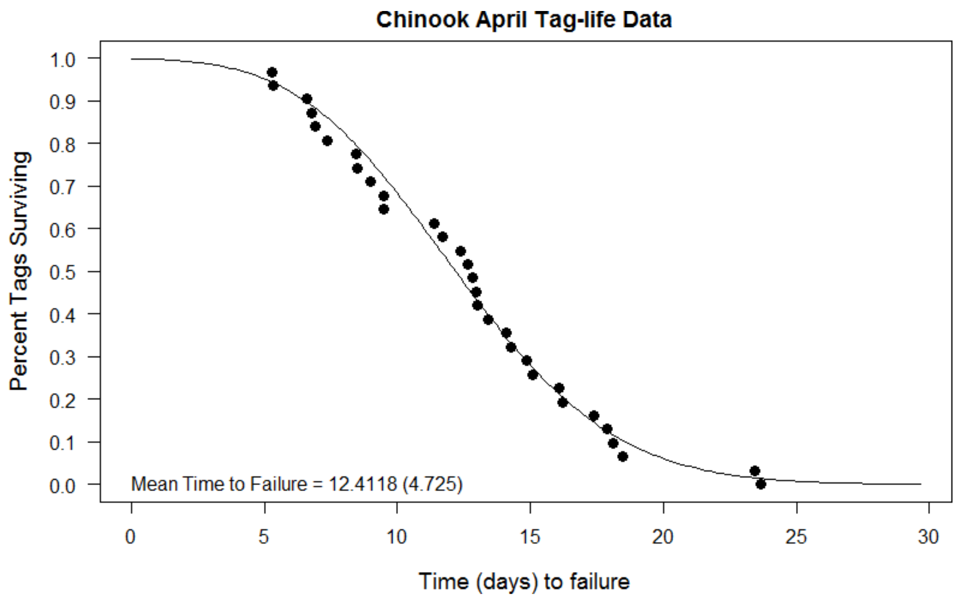


**Figure 14. Observed tag failure times from the April 2014 tag-life study of VEMCO V4 tags, and fitted four-parameter vitality curve. Tags in the April tag-life study had a programming error that affected the kill-time counter.**

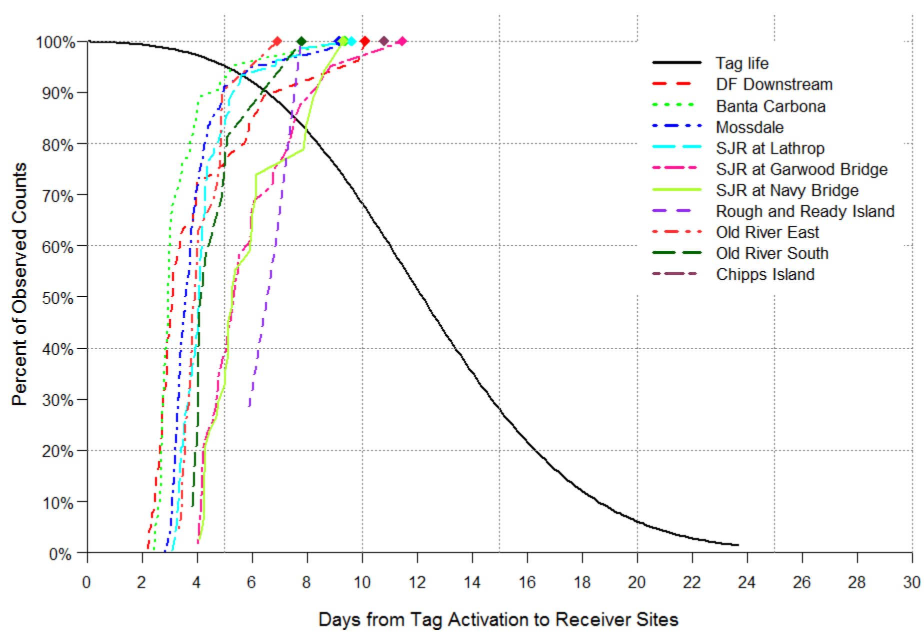


**Figure 15. Four-parameter vitality survival curve for tag survival from April tag-life study, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon from the mid-April release group at receivers used in Model IIIb in 2014, including detections that may have come from predators. The tags that provided these data (tag survival and arrival timing) had a programming error that affected the kill-time counter.**

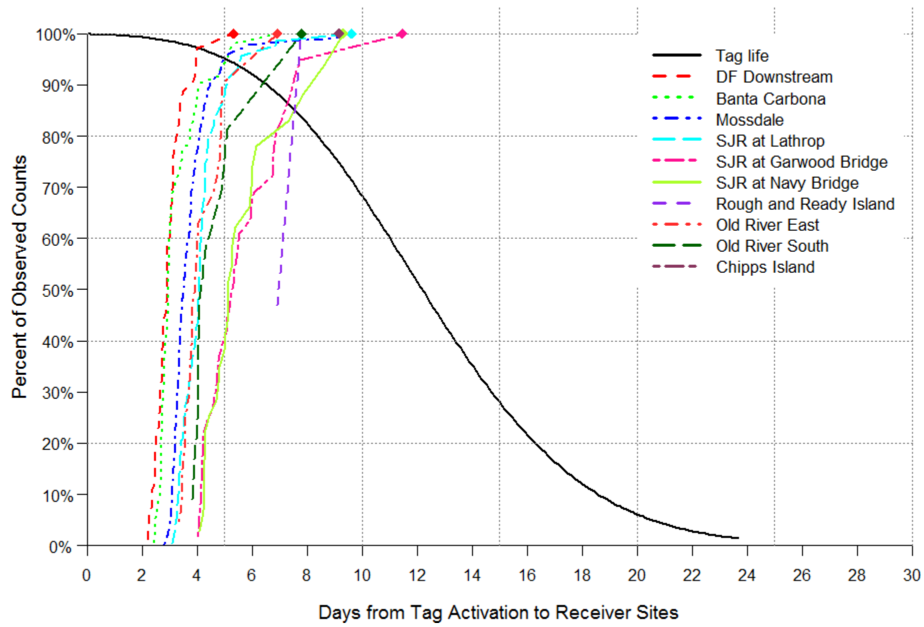


**Figure 16. Four-parameter vitality survival curve for tag survival from April tag-life study, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon from the mid-April release group at receivers used in Model IIIb in 2014, excluding detections that may have come from predators. The tags that provided these data (tag survival and arrival timing) had a programming error that affected the kill-time counter.**

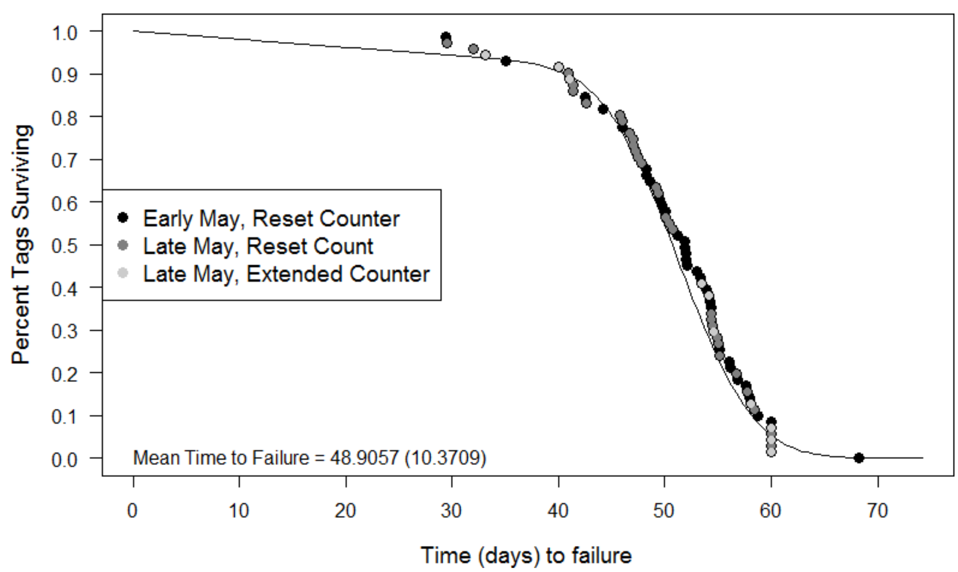


**Figure 17. Observed tag failure times from the May 2014 tag-life studies of VEMCO V4 tags, pooled over the early May and late May studies, and fitted four-parameter vitality curve. Tags in the May tag-life studies did not have the kill-time counter programming error.**

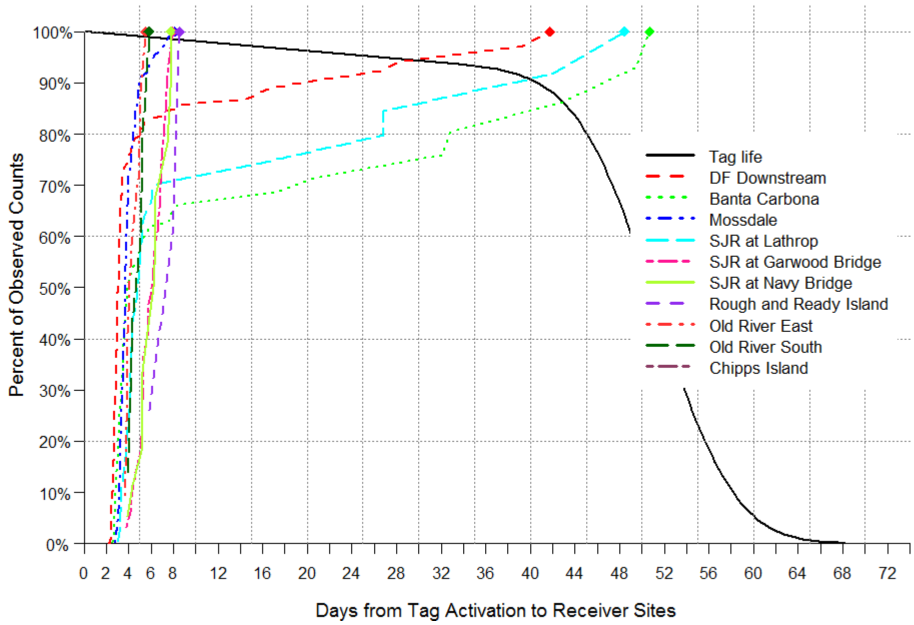


**Figure 18. Four-parameter vitality survival curve for tag survival from May tag-life studies, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon from the late April and May release groups at receivers used in Model IIIb in 2014, including detections that may have come from predators. The tags that provided these data (tag survival and arrival timing) did not have the kill-time counter programming error.**

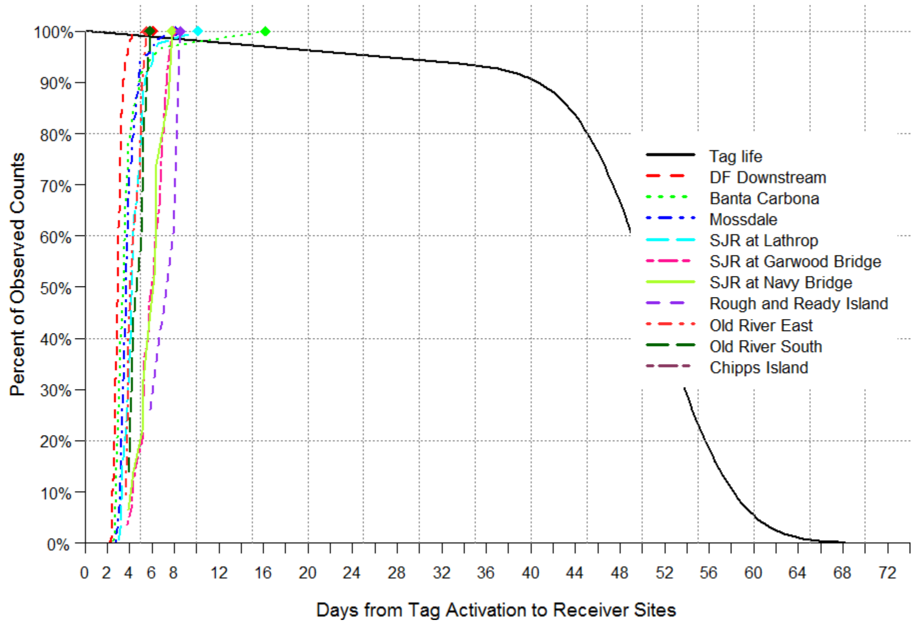


**Figure 19. Four-parameter vitality survival curve for tag survival from May tag-life studies, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon from the late April and May release groups at receivers used in Model IIIb in 2014, excluding detections that may have come from predators. The tags that provided these data (tag survival and arrival timing) did not have the kill-time counter programming error.**

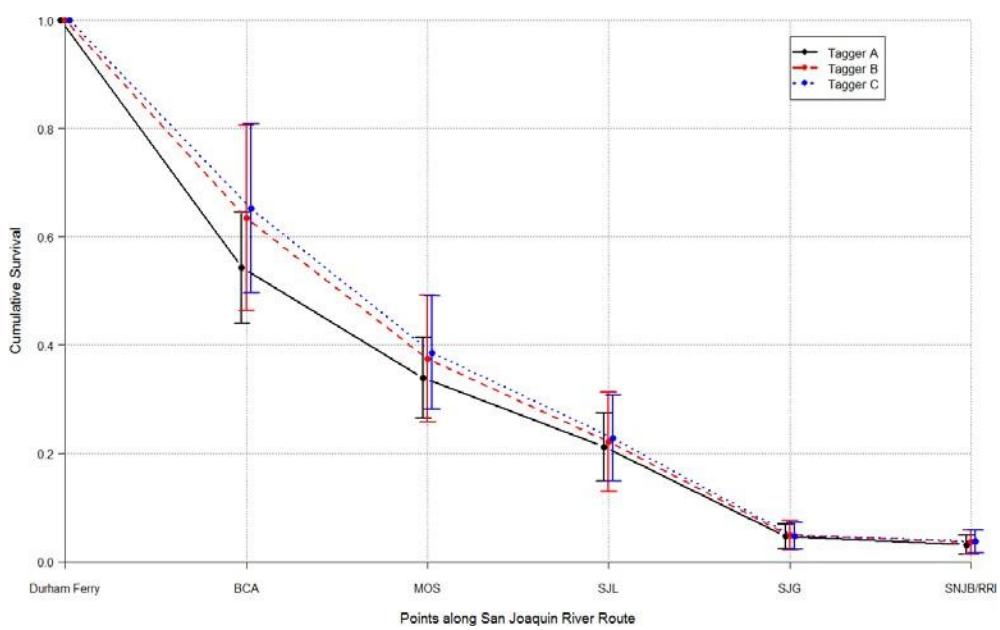


**Figure 20. Cumulative survival from release at Durham Ferry to various points along the San Joaquin River route, by surgeon (tagger). Error bars are 95% confidence intervals.**

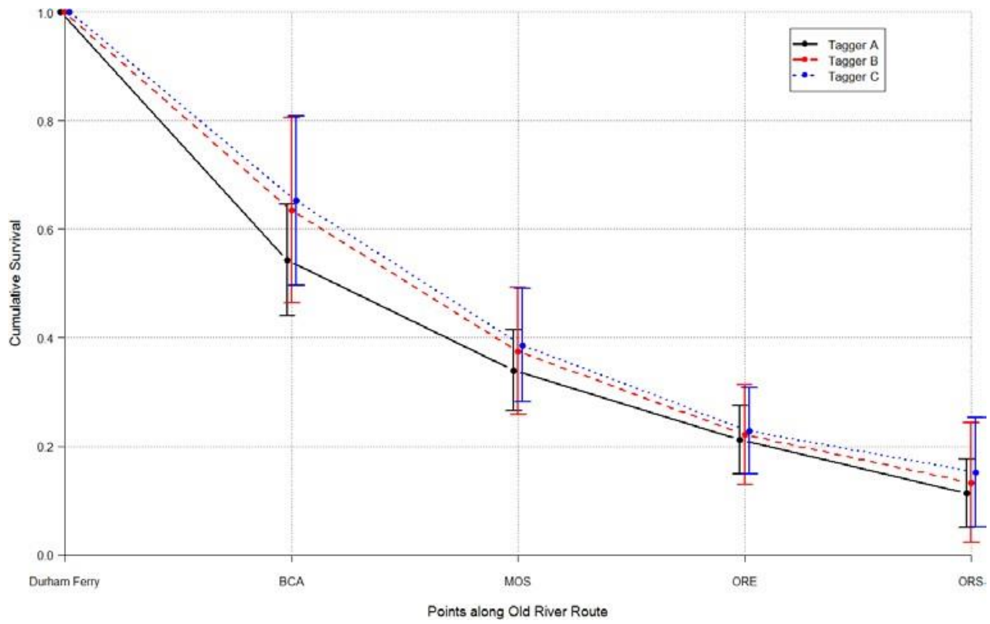


**Figure 21. Cumulative survival from release at Durham Ferry to various points along the Old River route, by surgeon (tagger). Error bars are 95% confidence intervals.**

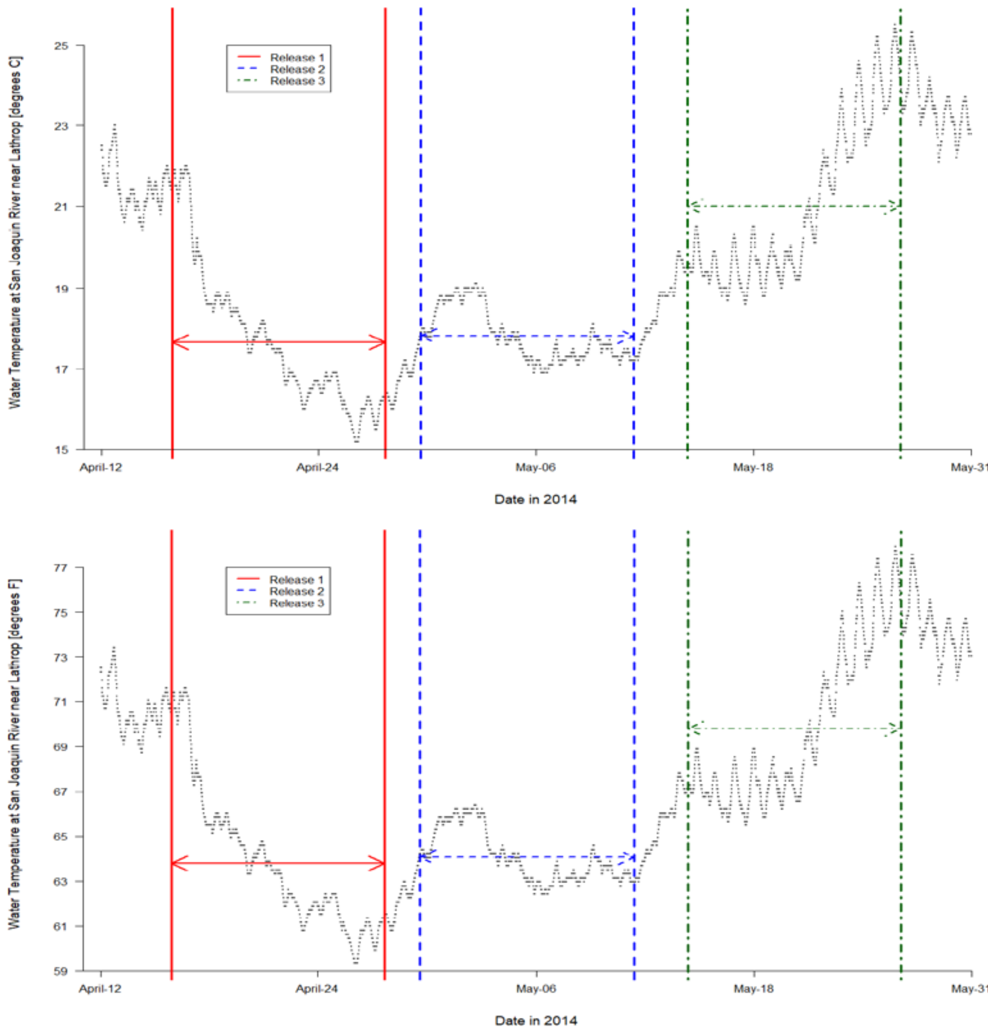


**Figure 22. Water temperature (°C, top graphs and °F, bottom graphs) at the San Joaquin River gaging station near Lathrop during the 2014 study. Vertical lines represent period from first day of release to 8 d after last day of release. Arrow height indicates mean temperature during travel period (63.8 °F, 64.1 °F, and 70.0 °F shown in bottom graphs for the three release groups, respectively).**

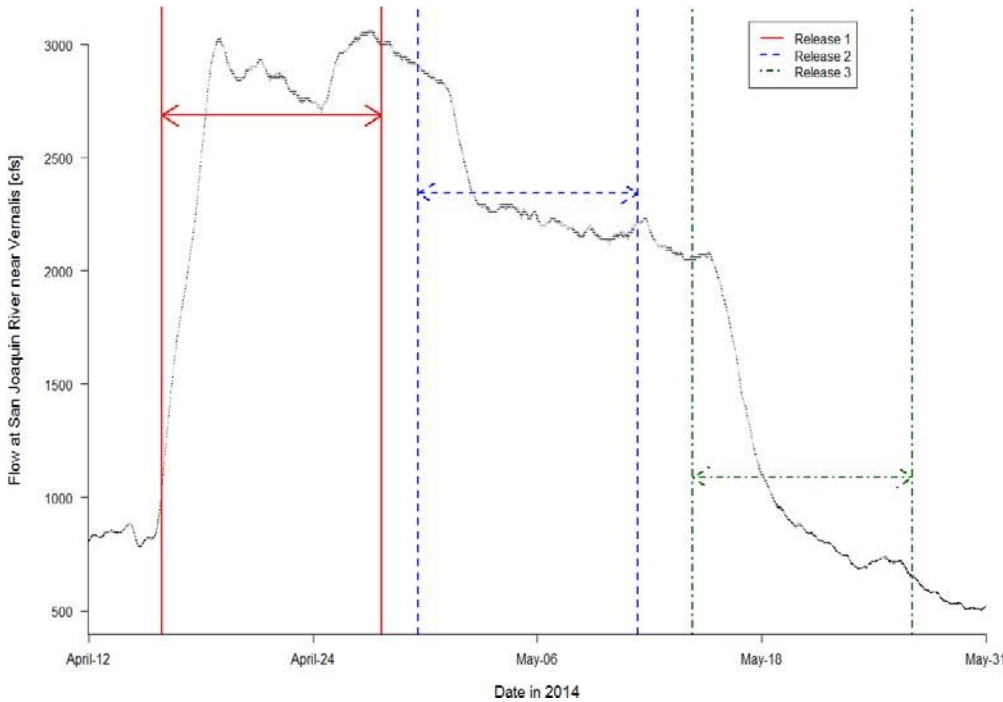


**Figure 23. River discharge (cfs) at Vernalis during the 2014 study. Vertical lines represent period from first day of release to 8 d after last day of release. Arrow height indicates mean flow during travel period: 2,685 cfs, 2,341 cfs, and 1,090 cfs for the three release groups, respectively.**

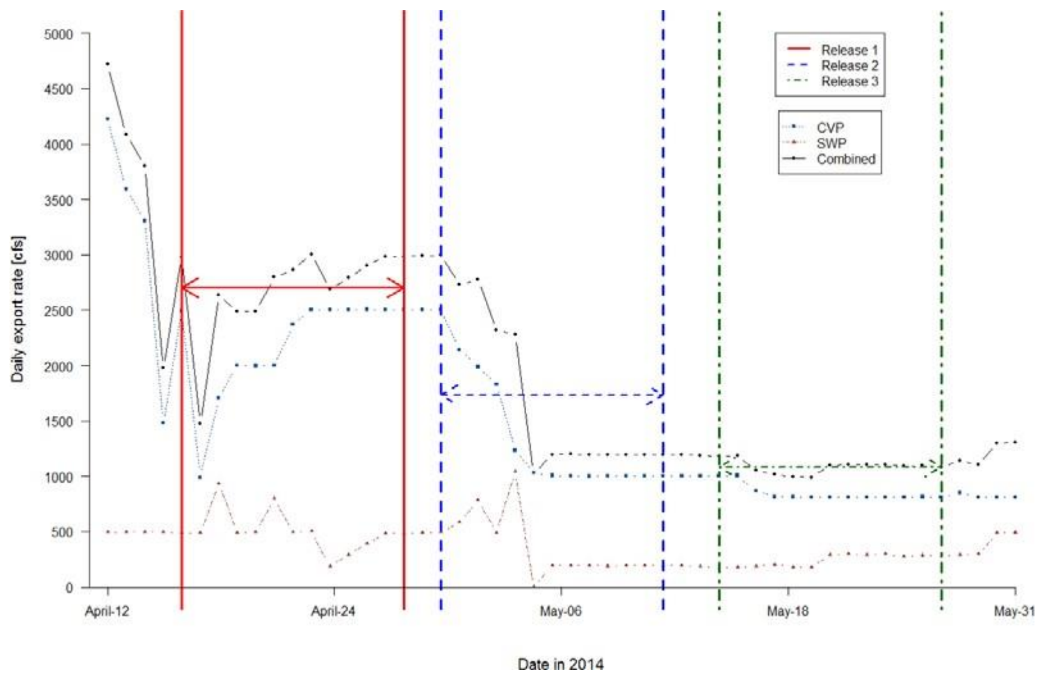


**Figure 24. Daily export rate (cfs) at CVP and SWP during 2014 study. Vertical lines represent period from first day of release to 8 d after last day of release. Arrow height indicates mean combined export rate during travel period: 2,700 cfs, 1,830 cfs, and 1,085 cfs for the three release groups, respectively.**

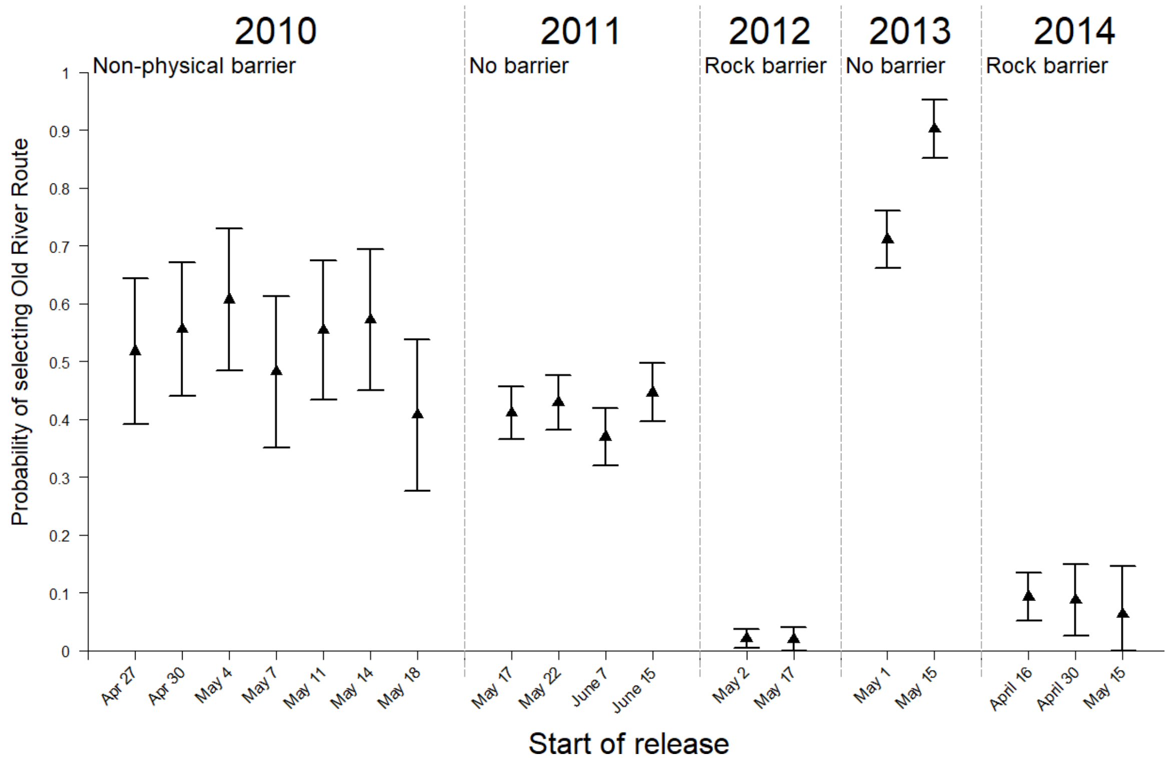


**Figure 25. Estimated probabilities of selecting the Old River route at the head of Old River for each study year and release group; bars indicate asymptotic 95% confidence intervals.**

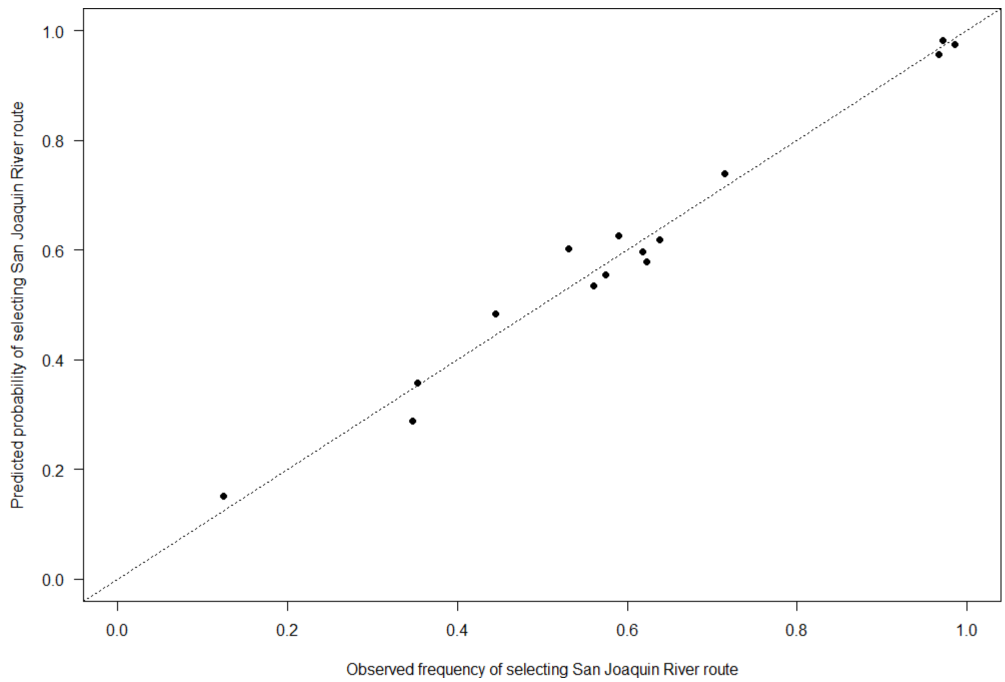


Figure 26. Predicted probability versus observed frequency of selecting the San Joaquin River route for the route selection models. Dashed line is 1-1 line.

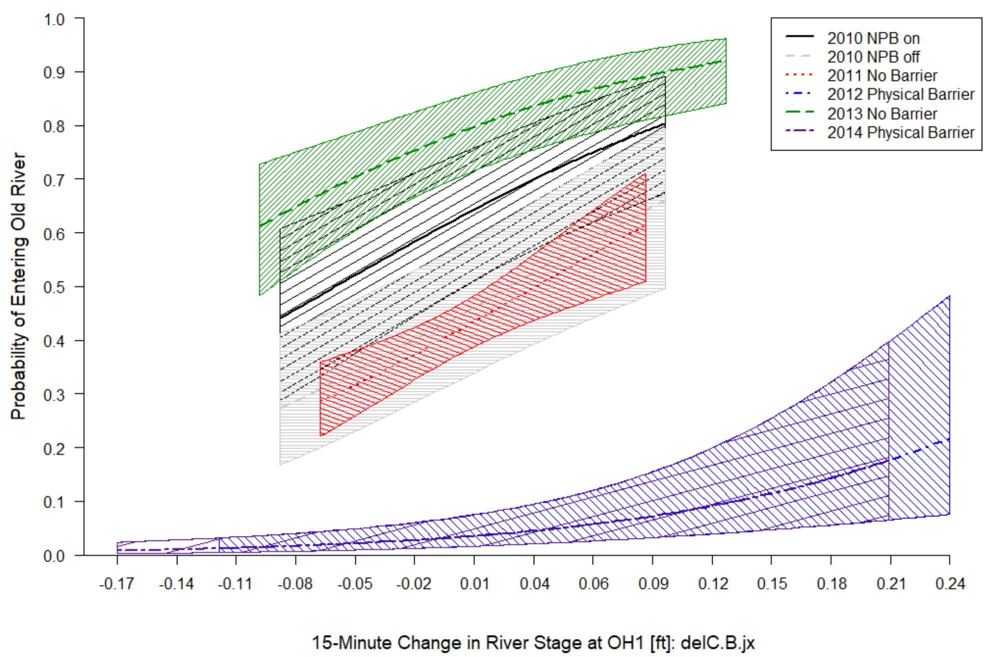


Figure 27. Predicted probability of entering Old River at the head of Old River as a function of the 15-minute change in river stage at the OH1 gaging station (ΔCB) upon fish arrival time at the head of Old River. Shaded area = 95% confidence band.

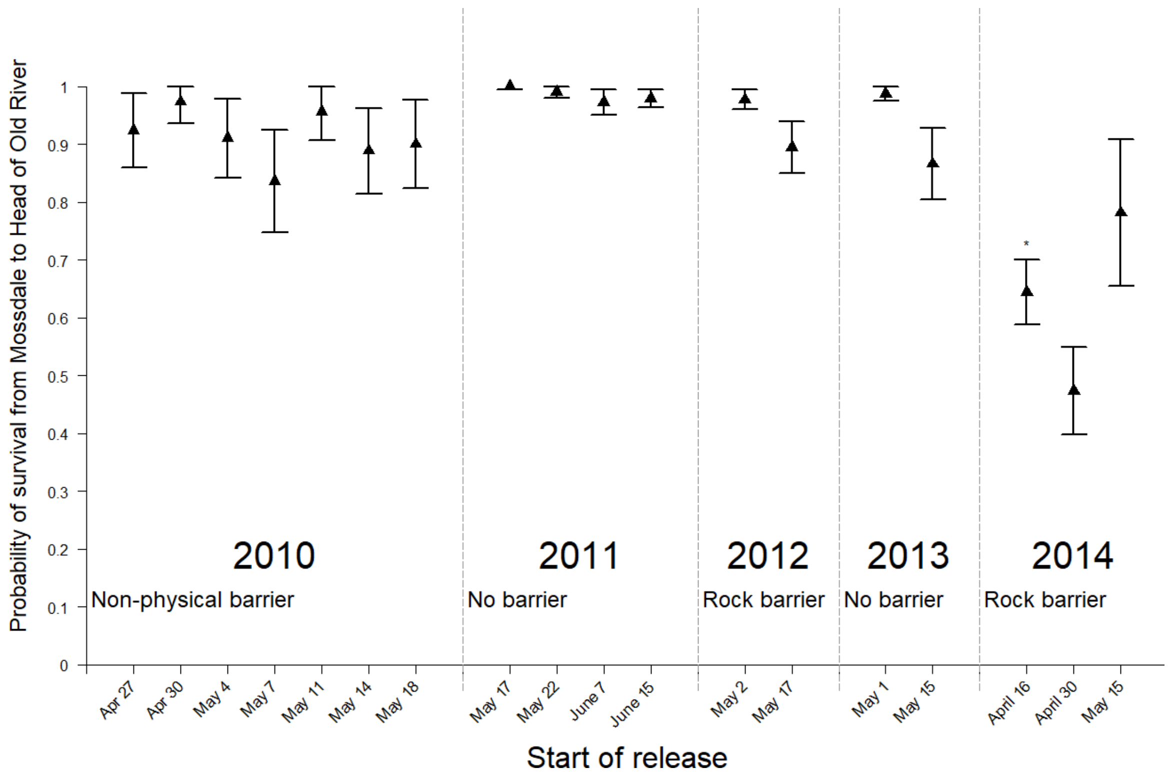


**Figure 28. Estimated probabilities of surviving from MOS to the receivers just downstream of the head of Old River (SJL, ORE), for each study year and release group; bars indicate asymptotic 95% confidence intervals. Asterisk indicates the joint probability of fish survival and tag survival in presence of high rate of premature tag failure.**

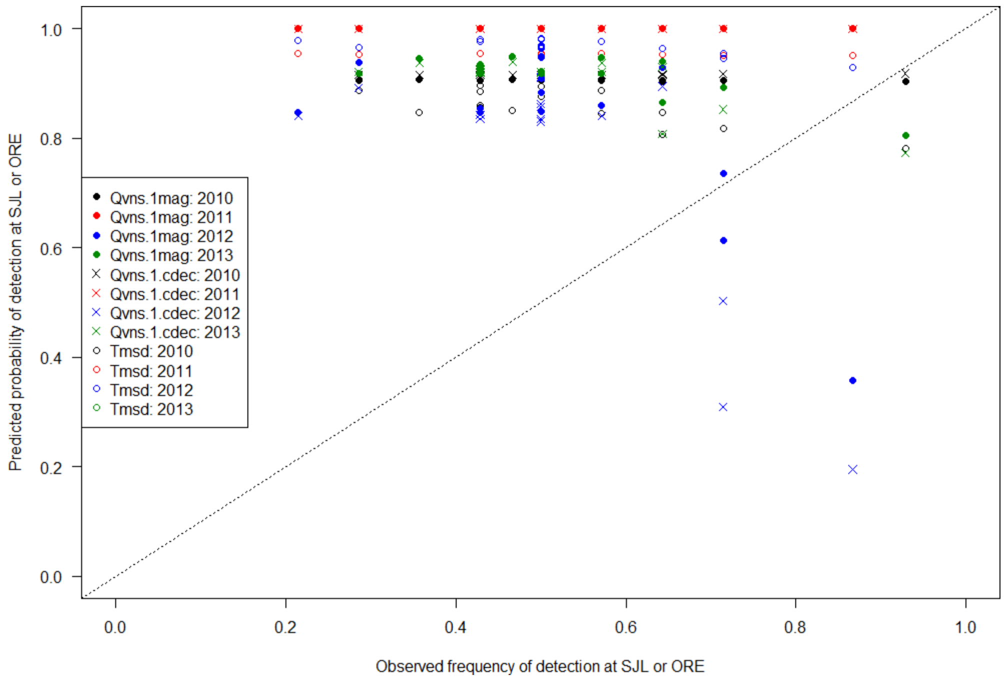


**Figure 29. Predicted probability versus observed frequency of surviving from Mossdale to the head of Old River and detection at SJL or ORE for the year-specific survival models previously developed for 2010-2013 (Buchanan 2017). Predictions were based on year-specific models developed for 2010-2013, and were compared to observed data from the second and third release groups of 2014. The covariate and year that define the prediction model are identified. Dashed line is 1-1 line. Variable names are defined in Table 34 of Buchanan (2017).**

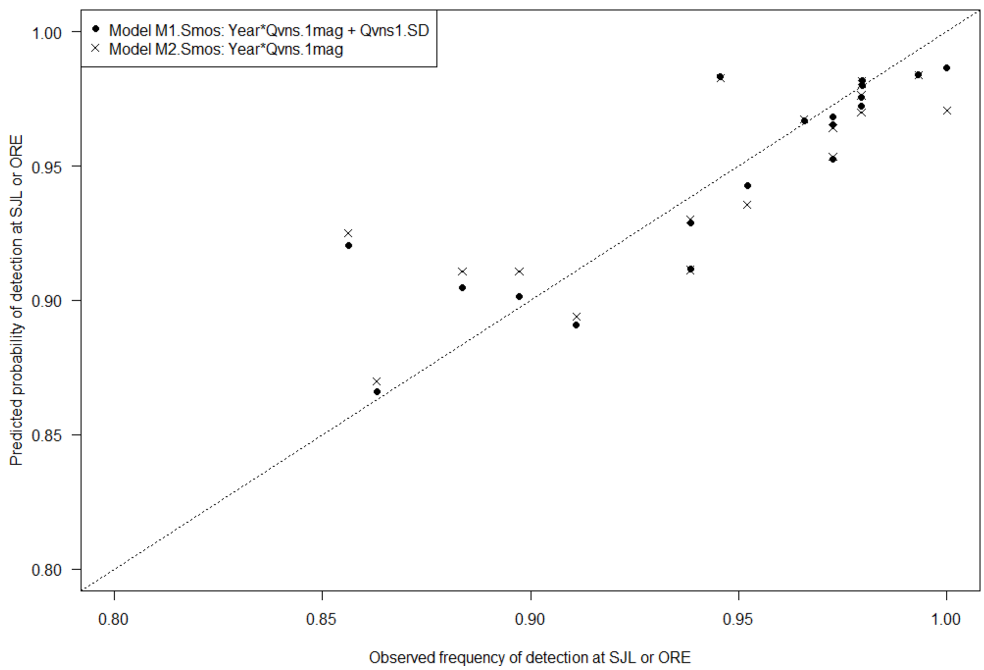


**Figure 30. Predicted probability versus observed frequency of surviving from Mossdale to the head of Old River and detection at SJL or ORE for the two models considered. Dashed line is 1-1 line.**

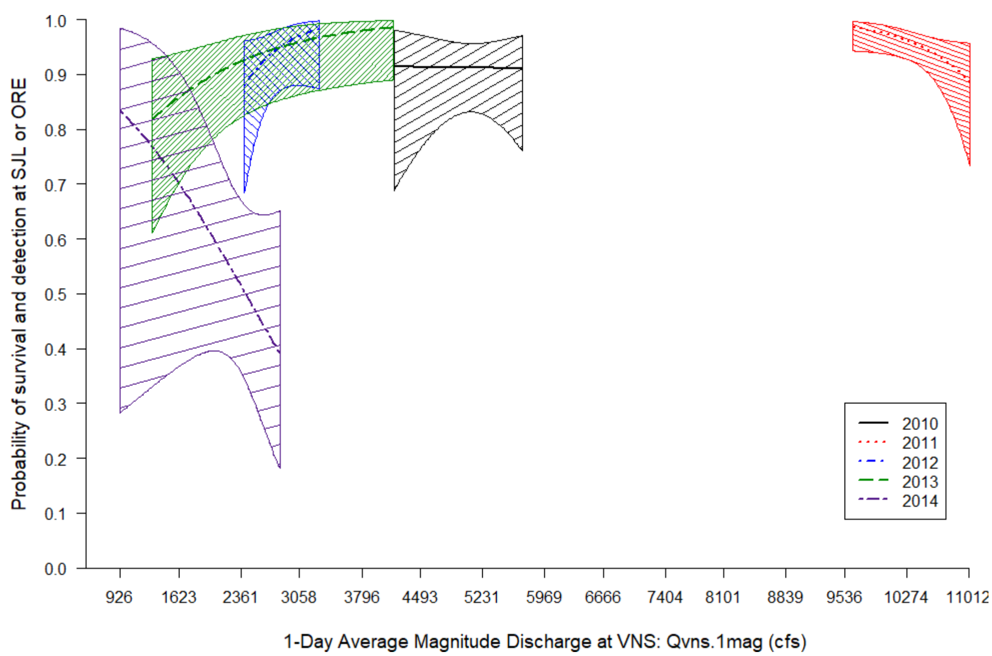


**Figure 31. Predicted probability of surviving from Mossdale to the head of Old River and detection at SJL or ORE for each year, plotted as a function of observed 1-day average magnitude of river flow at the VNS gage from the time of tag release at Durham Ferry, by Model M1.Smos:** $\lambda - Year + Q_{VNS.1mag} + Year \times Q_{VNS.1mag} + Q_{VNS1.SD}$ **. Shaded area = 95% confidence band.**

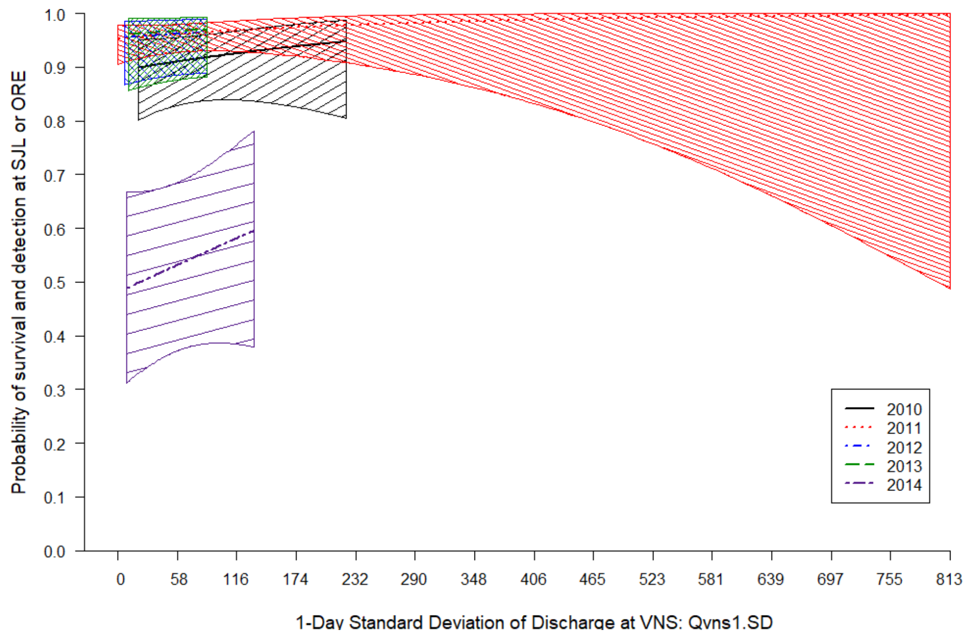


**Figure 32. Predicted probability of surviving from Mossdale to the head of Old River and detection at SJL or ORE for each year, plotted as a function of observed 1-day standard deviation of river flow at the VNS gage from the time of tag release at Durham Ferry, by Model M1.Smos:** $\lambda - Year + Q_{VNS.1mag} + Year \times Q_{VNS.1mag} + Q_{VNS1.SD}$. **Shaded area = 95% confidence band.**

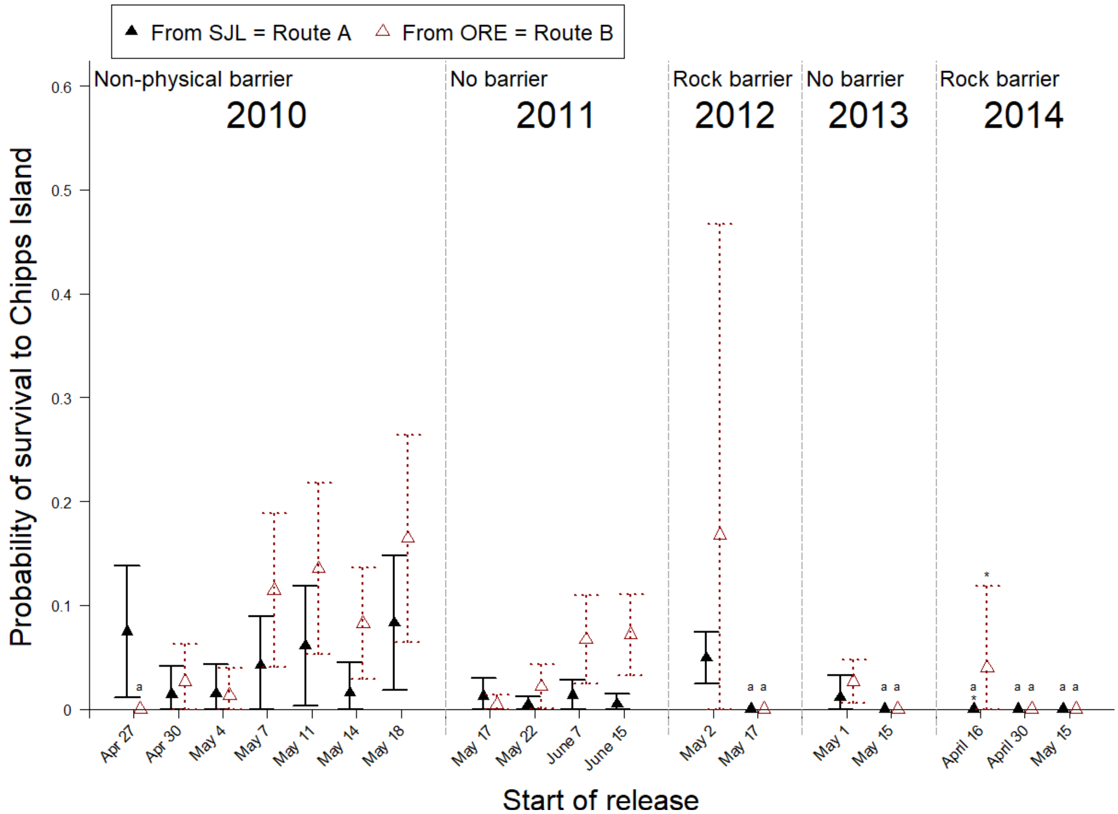


**Figure 33. Estimated probabilities of surviving to Chipps Island for the San Joaquin River route (Route A) and the Old River route (Route B), for each study year and release group; bars indicate asymptotic 95% confidence intervals. Asterisk indicates the joint probability of fish survival and tag survival in presence of high rate of premature tag failure. Letter "a" indicates no tags detected at Chipps Island.**

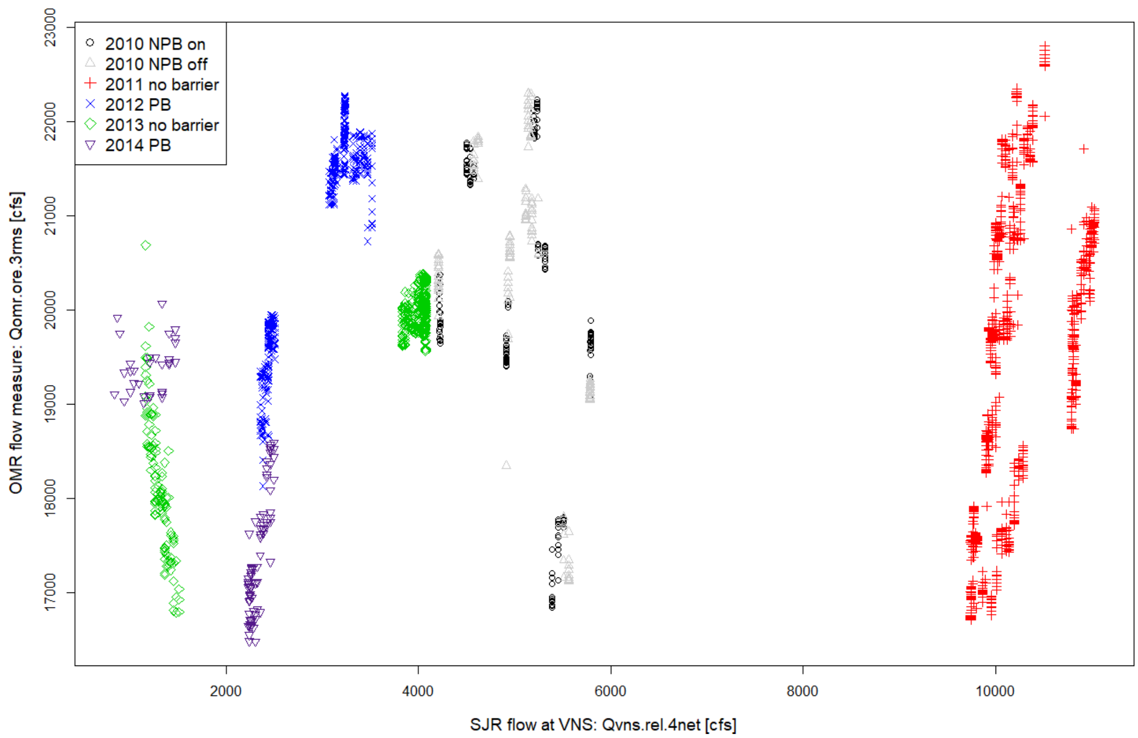


**Figure 34. Observed 4-day average of net San Joaquin River discharge at VNS from release of tagged fish and 3-day root mean square (RMS) of the sum of Old River discharge at ORB and Middle River discharge at MID (="OMR") from tag detection at ORE, coded by year and barrier status (r = -0.05 for all years combined). NPB = non-physical barrier, PB = physical barrier.**

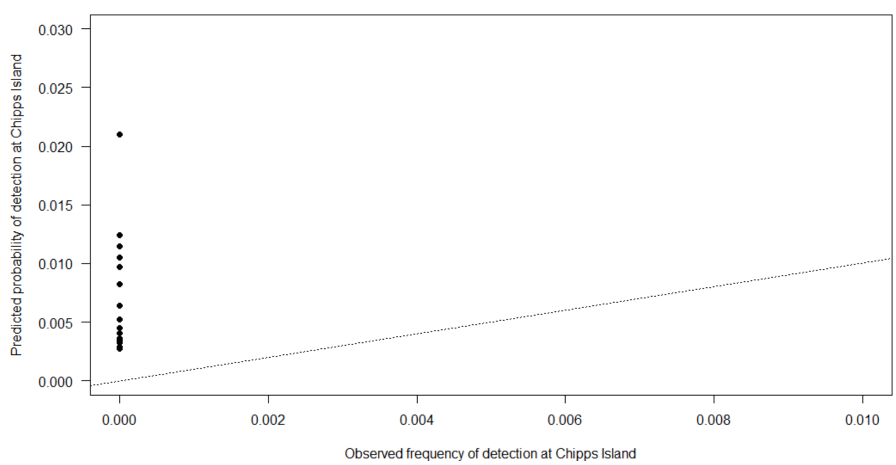


**Figure 35. Predicted probability versus observed frequency of the joint event of survival to and detection at Chipps Island for the model previously developed for 2010-2013 (Buchanan 2017) and data from the second and third release groups of 2014. Model structure was: S ~ Route + QORB. Dashed line is 1-1 line.**

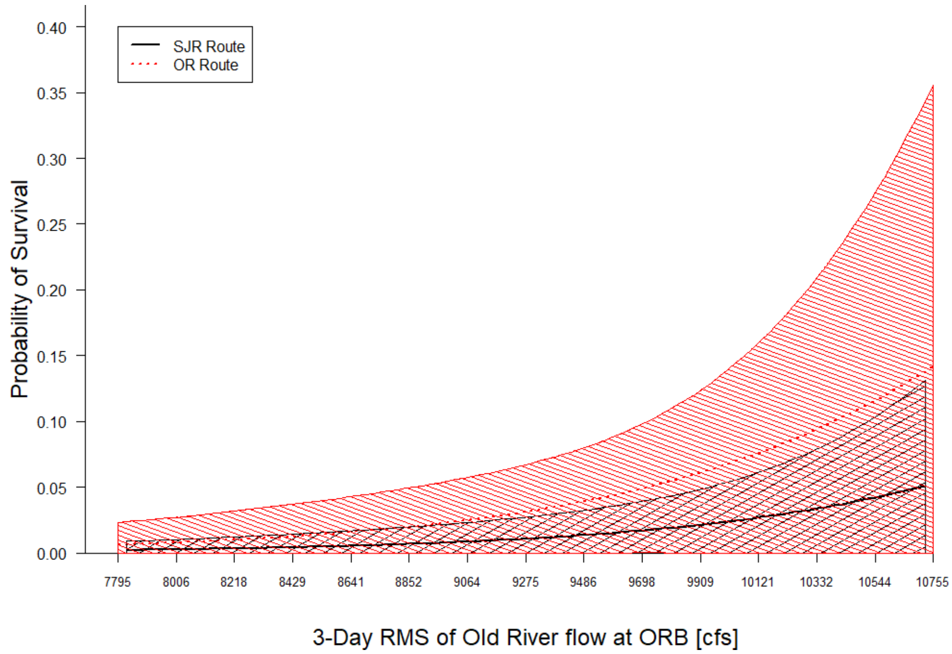


**Figure 36. Predicted probability and 95% confidence band of surviving from the head of Old River (SJL or ORE receivers) to Chipps Island as a function of the 3-day Root Mean Square of Old River discharge (flow) at the ORB gaging station, from route effects model: S ~ Route + QORB.**

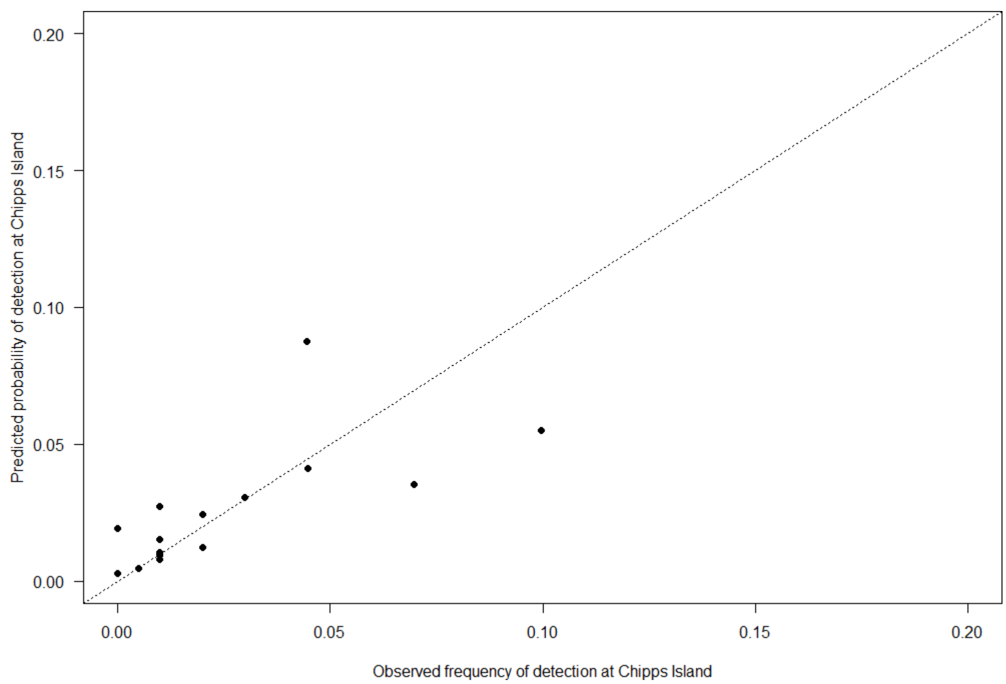


**Figure 37. Predicted probability versus observed frequency of the joint event of survival to and detection at Chipps Island for the selected route effects model for survival to Chipps Island from the head of Old River: S ~ Route + QORB. Dashed line is 1-1 line.**

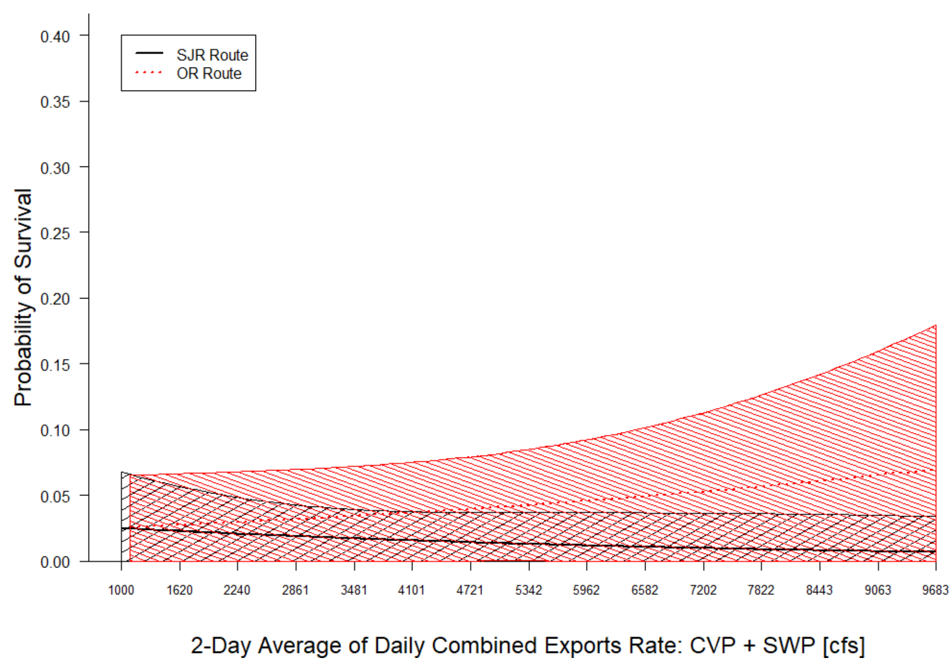


**Figure 38. Predicted probability and 95% confidence band of surviving from the head of Old River (SJL or ORE receivers) to Chipps Island as a function of the 2-day average of combined daily export rates from CVP and SWP, from route effects model: S ~ Route × CVPSWP.**

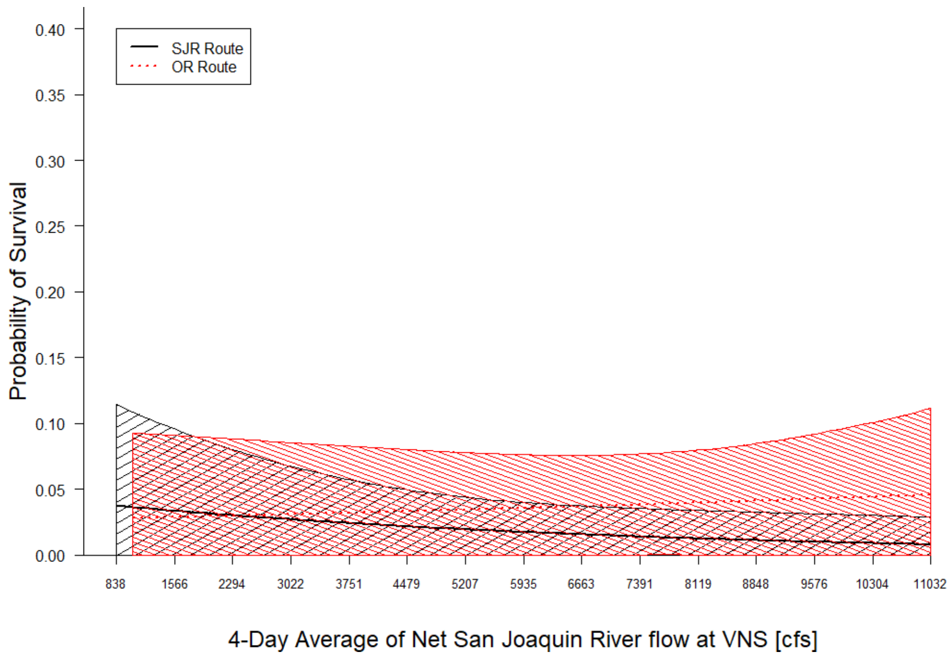


**Figure 39. Predicted probability and 95% confidence band of surviving from the head of Old River (SJL or ORE receivers) to Chipps Island as a function of the 4-day average of net San Joaquin River discharge (flow) at the VNS gaging station, from route effects model: S ~ Route × QVNS.**

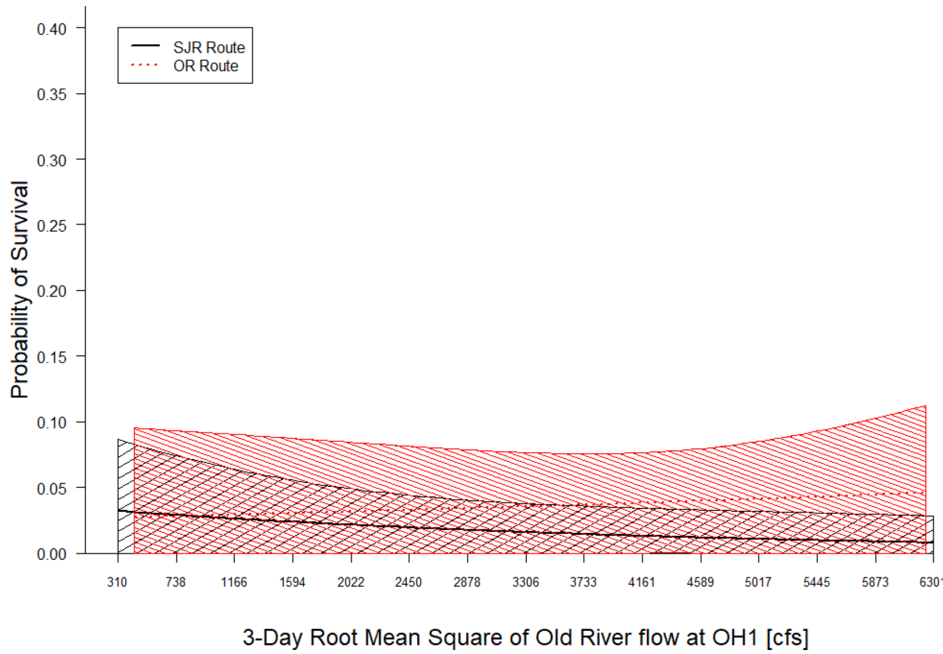


**Figure 40. Predicted probability and 95% confidence band of surviving from the head of Old River (SJL or ORE receivers) to Chipps Island as a function of the 3-day Root Mean Square of Old River discharge (flow) at the OH1 gaging station, from route effects model: S ~ Route × QOH1.**

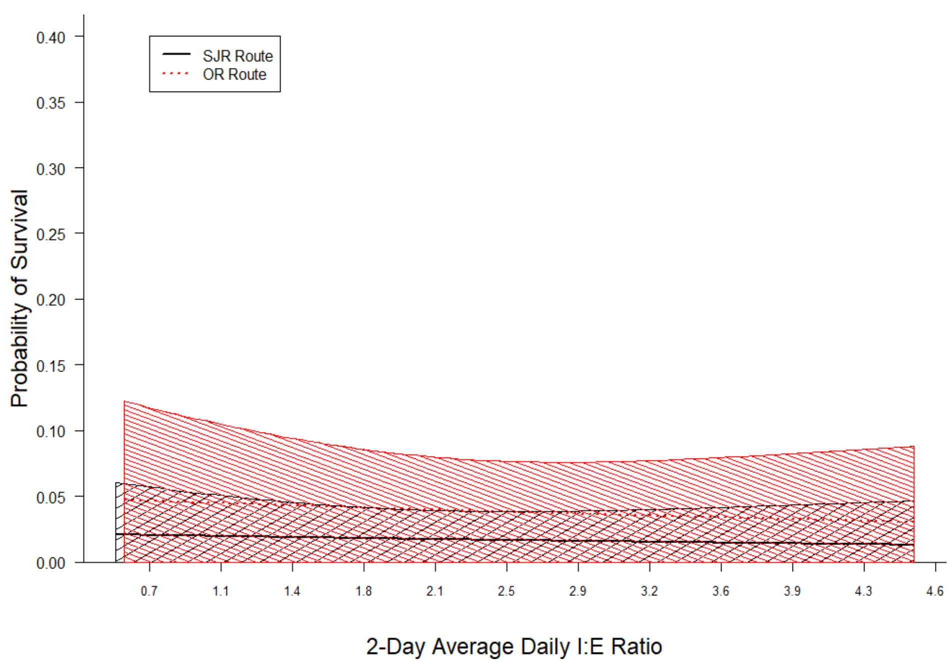


**Figure 41. Predicted probability and 95% confidence band of surviving from the head of Old River (SJL or ORE receivers) to Chipps Island as a function of the 2-day average of the I:E ratio (I:E = Delta inflow at Vernalis/combined exports), from route effects model: S ~ Route × IE.2.**

# Tables

**Table 1. Tagging, transport, and holding dates and times and the number released by tank number for Chinook Salmon as part of the 2014 Salmon Survival Study. Fish were released over a 24 h period (Release A, B, C, and D) after being held for a minimum of 24 h.**

| Tagging Date | Transport Date; Start – End Transport Time | Start Holding Date; Time | Tank # | Release A Date; Time | Release A Number released | Release B Date; Time | Release B Number released | Release C Date; Time | Release C Number released | Release D Date; Time | Release D Number released | Total released (A+B+C+D) | Number of Dummy-tagged fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/15/2014 | 4/15/14; 1146-1309 | 4/15/14; 1415 | 1 | 4/16; 1901,1902 | 45 | | | | | | | 162 | 3 |
| | | | 2 | | | 4/17; 0103, 0106 | 36 | | | | | | 3 |
| | 4/15/14; 1520-1615 | 4/15/14; 1658 | 3 | | | 4/17; 0106 | 9 | 4/17; 0659 | 45 | 4/17; 1404 | 27 | | 9 |
| | | | | | | | | | | | | | |
| 4/16/2014 | 4/16/14; 1100-1218 | 4/16/14; 1322 | 1 | 4/17; 1858, 1859 | 45 | | | | | | | 162 | 3 |
| | | | 2 | | | 4/18; 0105 | 36 | | | | | | 3 |
| | 4/16/14; 1420-1514 | 4/16/14; 1618 | 3 | | | 4/18; 0105 | 9 | 4/18; 0652 | 30 | 4/18; 1348 | 42 | | 9 |
| | | | | | | | | | | | | | |
| 4/17/2014 | 4/17/14; 1116 - 1228 | 4/17/14; 1350 | 1 | 4/18; 1900, 1901 | 44 | | | | | | | 161 | 9 |
| | | | 2 | | | 4/19; 0106 | 30 | 4/19; 0700 | 6 | | | | 12 |
| | 4/17/14; 1435 - 1534 | 4/17/14; 1630 | 3 | | | | | 4/19; 0700 | 39 | 4/19; 1307 | 42 | | 9 |
| | | | | | | | | | | | | | |

Table 1 (continued)

| Tagging Date | Transport Date; Start – End Transport Time | Start Holding Date; Time | Tank # | Release A Date; Time | Release A Number released | Release B Date; Time | Release B Number released | Release C Date; Time | Release C Number released | Release D Date; Time | Release D Number released | Total released (A+B+C+D) | Number of Dummy-tagged fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/18/2014 | 4/18/14; 1100 - 1212 | 4/18/14; 1334 | 1 | 4/19; 1904 | 30 | 4/20; 0058 | 15 | | | | | 158 | 3 |
| | | | 2 | | | 4/20; 0058 | 29 | 4/20; 0655 | 6 | | | | 3 |
| | 4/18/14; 1345 - 1445 | 4/18/14; 1545 | 3 | | | | | 4/20; 0655 | 38 | 4/20; 1305, 1306 | 40 | | 9 |
| Total | | | | | | | | | | | | 643 | |
| 4/29/2014 | 4/29/14; 1112 - 1224 | 4/29/14; 1310 | 1 | 4/29; 1858, 1859 | 45 | | | | | | | 161 | 3 |
| | | | 2 | | | 5/1; 0055 | 35 | | | | | | 3 |
| | 4/29/14; 1435 - 1538 | 4/29/14; 1618 | 3 | | | 5/1; 0055 | 9 | 5/1; 0657 | 45 | 5/1; 1302 | 27 | | 9 |
| | | | | | | | | | | | | | |
| 4/30/2014 | 4/30/14; 1056 - 1213 | 4/30/14; 1301 | 1 | 5/1; 1900, 1901 | 45 | | | | | | | 162 | 3 |
| | | | 2 | | | 5/2; 0057 | 36 | | | | | | 3 |
| | 4/30/14; 1422 - 1522 | 4/30/14; 1605 | 3 | | | 5/2; 0057 | 9 | 5/2; 0656 | 30 | 5/2; 1346 | 42 | | 9 |
| | | | | | | | | | | | | | |
| 5/1/2014 | 5/1/14; 1045 - 1203 | 5/1/14; 1251 | 1 | 5/2; 1858 | 45 | | | | | | | 161 | 3 |
| | | | 2 | | | 5/3; 0057 | 30 | 5/3; 0655 | 6 | | | | 3 |
| | 5/1/14; 1359 - 1500 | 5/1/14; 1545 | 3 | | | | | 5/3; 0655 | 38 | 5/3; 1259 | 42 | | 9 |
| | | | | | | | | | | | | | |

**Table 1 (continued)**

| Tagging Date | Transport Date; Start – End Transport Time | Start Holding Date; Time | Tank # | Release A Date; Time | Release A Number released | Release B Date; Time | Release B Number released | Release C Date; Time | Release C Number released | Release D Date; Time | Release D Number released | Total released (A+B+C+D) | Number of Dummy-tagged fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/2/2014 | 5/2/14; 1130 - 1224 | 5/2/14; 1335 | 1 | 5/3; 1900 | 30 | 5/4; 0058 | 15 | | | | | 162 | 9 |
| | | | 2 | | | 5/4; 0058 | 30 | 5/4; 0655 | 6 | | | | 12 |
| | 5/2/14; 1410 - 1513 | 5/2/14; 1550 | 3 | | | | | 5/4; 0655 | 39 | 5/4; 1302 | 42 | | 9 |
| Total | | | | | | | | | | | | 646 | |
| 5/14/2014 | 5/14/14; 1100 - 1214 | 5/14/14; 1310 | 1 | 5/15; 1903, 1904 | 45 | | | | | | | 162 | 3 |
| | | | 2 | | | 5/16; 0055 | 36 | | | | | | 3 |
| | 5/14/14; 1410 - 1510 | 5/14/14; 1551 | 3 | | | 5/16; 0055 | 9 | 5/16; 0657 | 45 | 5/16; 1304 | 27 | | 9 |
| | | | | | | | | | | | | | |
| 5/15/2014* | 5/15/14; 1110 - 1224 | 5/15/14; 1320 | 3 | 5/16; 1901, 1903 | 45 | 5/17; 0059 | 36 | | | | | 161 | 9 |
| | 5/15/14; 1607 - 1709 | 5/15/14; 1748 | 2 | | | 5/17; 0059 | 9 | 5/17; 0657 | 29 | 5/17; 1316 | 6 | | 3 |
| | | | 1 | | | | | | | 5/17; 1316 | 36 | | 3 |
| | | | | | | | | | | | | | |
| 5/16/2014 | 5/16/14; 1045 - 1159 | 5/16/14; 1239 | 2 | 5/17; 1858, 1859 | 45 | | | | | | | 162 | 3 |
| | | | 1 | | | 5/18; 0056 | 30 | 5/18; 0657 | 6 | | | | 3 |
| | 5/16/14; 1340 - 1441 | 5/16/14; 1513 | 3 | | | | | 5/18; 0657 | 39 | 5/18; 1305, 1306 | 42 | | 9 |

**Table 1 (continued)**

| Tagging Date | Transport Date; Start – End Transport Time | Start Holding Date; Time | Tank # | Release A Date; Time | Release A Number released | Release B Date; Time | Release B Number released | Release C Date; Time | Release C Number released | Release D Date; Time | Release D Number released | Total released (A+B+C+D) | Number of Dummy-tagged fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/17/2014 | 5/17/14; 1100 - 1212 | 5/17/14; 1302 | 2 | 5/18; 1858 | 30 | 5/19; 0057 | 15 | | | | | 144 | 9 |
| | | | 1 | | | 5/19; 0057 | 30 | 5/19; 0657 | 6 | | | | 12 |
| | 5/17/14; 1356 - 1455 | 5/16/14; 1530 | 3 | | | | | 5/19; 0657 | 39 | 5/19; 1300 | 24 | | 9 |
| Total | | | | | | | | | | | | 629 | |

**Table 2. Transport dates, transport tank number, loading time (24 h), water temperature and dissolved oxygen (DO) in the transport tank after loading, after transport, and in the river, and mortalities (morts) after transport and before release for Chinook Salmon released as part of the 2014 Salmon Survival Study.**

| Date | Tank # | Loading time | Tank after loading | | Tank after transport | | # morts after transport | River | | # morts just prior to release |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Temp (˚C) | DO (mg/L) | Temp (˚C) | DO (mg/L) | | Temp (˚C) | DO (mg/L) | |
| 4/15/2014 | 1 | 0906 | 13.3 | 10.47 | 14.7 | 14.35 | 0 | 20.8 | 12.50 | 0 |
| 4/15/2014 | 2 | 0906 | 13.4 | 10.50 | 15.1 | 15.11 | 0 | 20.8 | 12.50 | 0 |
| 4/15/2014 | 3 | 1252 | 14.7 | 11.36 | 16.5 | 11.95 | 0 | 22.10 | 12.80 | 0 |
| 4/16/2014 | 1 | 0845 | 13.6 | 10.30 | 14.5 | 13.25 | 0 | 16.5 | 10.80 | 0 |
| 4/16/2014 | 2 | 0845 | 13.2 | 10.83 | 14.6 | 15.78 | 0 | 16.5 | 10.80 | 0 |
| 4/16/2014 | 3 | 1209 | 13.8 | 11.65 | 16.4 | 12.14 | 0 | 17.6 | 11.40 | 0 |
| 4/17/2014 | 1 | 0845 | 13.3 | 10.46 | 14.6 | 13.28 | 0 | 16.8 | 10.80 | 0 |
| 4/17/2014 | 2 | 0845 | 13.4 | 10.41 | 14.7 | 12.85 | 0 | 16.8 | 10.80 | 0 |
| 4/17/2014 | 3 | 1217 | 13.5 | 11.76 | 15.3 | 12.77 | 0 | 17.8 | 11.70 | 0 |
| 4/18/2014 | 1 | 0900 | 13.3 | 10.67 | 14.5 | 12.62 | 0 | 17.4 | 10.30 | 0 |
| 4/18/2014 | 2 | 0900 | 13.1 | 10.65 | 14.6 | 13.49 | 1 | 17.4 | 10.30 | 0 |
| 4/18/2014 | 3 | 1143 | 13.7 | 11.72 | 14.9 | 12.62 | 0 | 18.1 | 10.30 | 0 |
| AVG | | | 13.53 | 10.90 | 15.03 | 13.35 | | 18.22 | 11.25 | |

**Table 2. (continued)**

| Date | Tank # | Loading time | Tank after loading | | Tank after transport | | # morts after transport | River | | # morts just prior to release |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Temp (˚C) | DO (mg/L) | Temp (˚C) | DO (mg/L) | | Temp (˚C) | DO (mg/L) | |
| 4/29/2014 | 1 | 0845 | 13.1 | 10.58 | 14.5 | 13.84 | 0 | 15.9 | 11.30 | 0 |
| 4/29/2014 | 2 | 0845 | 13.3 | 10.60 | 14.5 | 13.88 | 0 | 15.9 | 11.30 | 0 |
| 4/29/2014 | 3 | 1221 | 13.7 | 11.83 | 15.0 | 12.35 | 0 | 16.8 | 10.80 | 0 |
| 4/30/2014 | 1 | 0855 | 13.3 | 10.59 | 15.3 | 13.13 | 0 | 16.6 | 10.10 | 0 |
| 4/30/2014 | 2 | 0855 | 13.3 | 10.72 | 15.1 | 13.70 | 0 | 16.6 | 10.10 | 0 |
| 4/30/2014 | 3 | 1155 | 14.0 | 11.89 | 15.4 | 12.12 | 0 | 17.6 | 11.10 | 0 |
| 5/1/2014 | 1 | 0840 | 13.6 | 10.51 | 15.0 | 12.40 | 0 | 16.7 | 10.70 | 0 |
| 5/1/2014 | 2 | 0840 | 13.3 | 10.63 | 15.0 | 12.54 | 0 | 16.7 | 10.70 | 0 |
| 5/1/2014 | 3 | 1152 | 14.0 | 12.85 | 15.5 | 13.03 | 0 | 17.7 | 10.50 | 0 |
| 5/2/2014 | 1 | 0840 | 13.3 | 10.60 | 15.0 | 12.08 | 0 | 17.4 | 10.90 | 0 |
| 5/2/2014 | 2 | 0840 | 13.4 | 10.54 | 14.9 | 13.00 | 0 | 17.4 | 10.90 | 0 |
| 5/2/2014 | 3 | 1216 | 13.9 | 11.85 | 15.7 | 12.21 | 0 | 18.0 | 11.60 | 0 |
| AVG | | | 13.52 | 11.10 | 15.08 | 12.86 | | 16.94 | 10.83 | |
| | | | | | | | | | | |
| 5/14/2014 | 1 | 0858 | 13.8 | 10.45 | 16.0 | 11.72 | 0 | 17.4 | 11.80 | 0 |
| 5/14/2014 | 2 | 0858 | 13.9 | 10.50 | 15.9 | 12.42 | 0 | 17.4 | 11.80 | 0 |
| 5/14/2014 | 3 | 1206 | 14.8 | 11.48 | 16.9 | 11.74 | 0 | 18.4 | 12.90 | 0 |
| 5/15/2014 | 1 | 1410 | 14.5 | 10.46 | 16.1 | 10.78 | 0 | 18.0 | 11.10 | 0 |
| 5/15/2014 | 2 | 1410 | 15.0 | 10.26 | 16.2 | 10.44 | 0 | 18.0 | 11.10 | 0 |
| 5/15/2014 | 3 | 0924 | 14.4 | 11.68 | 16.4 | 12.25 | 0 | 17.6 | 10.70 | 0 |
| 5/16/2014 | 1 | 0848 | 13.9 | 10.4 | 15.8 | 12.33 | 0 | 17.7 | 10.80 | 0 |
| 5/16/2014 | 2 | 0848 | 13.9 | 10.44 | 15.1 | 13.19 | 0 | 17.7 | 10.80 | 0 |
| 5/16/2014 | 3 | 1148 | 14.3 | 11.72 | 16.3 | 11.52 | 0 | 18.6 | 12.20 | 0 |
| 5/17/2014 | 1 | 0850 | 14.3 | 10.23 | 15.3 | 12.65 | 0 | 18.6 | 10.60 | 0 |
| 5/17/2014 | 2 | 0850 | 14.5 | 10.17 | 15.0 | 12.51 | 0 | 18.6 | 10.60 | 0 |
| 5/17/2014 | 3 | 1222 | 15.0 | 10.83 | 16.4 | 10.74 | 0 | 19.4 | 10.10 | 0 |
| AVG | | | 14.36 | 10.72 | 15.95 | 11.86 | | 18.12 | 11.21 | |

**Table 3. Characteristics assessed for Chinook Salmon smolt condition and short-term survival used in the 2014 Salmon Survival Study.**

| Character | Normal | Abnormal |
|---|---|---|
| Percent Scale Loss | Lower relative numbers based on 0-100% | Higher relative numbers based on 0-100% |
| Body Color | High contrast dark dorsal surfaces and light sides | Low contrast dorsal surfaces and coppery colored sides |
| Fin Hemorrhaging | No bleeding at base of fins | Blood present at base of fins |
| Eyes | Normally shaped | Bulging or with hemorrhaging |
| Gill Color | Dark beet red to cherry red colored gill filaments | Grey to light red colored gill filaments |
| Vigor | Active swimming (prior to anesthesia) | Lethargic or motionless (prior to anesthesia) |

**Table 4. Scoring rubric for assessing surgical technique of dummy-tagged fish held for 48 h at the release site.**

| Variable Name | Score | Description | Comments/Notes |
|---|---|---|---|
| Suture Present? | Scored Separately For Anterior and Posterior Sutures | | |
| | 0 | Yes | |
| | 1 | Yes, but untied or becoming untied | |
| | 2 | No | |
| Incision Apposition | 0 | Completely closed, perfect apposition | |
| | 1 | Incision partially open due to gape or overlap | |
| | 2 | Incision completely open (>75%) | |
| Fungus Present? | 0 | No fungus present | |
| | 1 | Fungus present | |
| Fungus Location | Describe the location of the fungus | | |
| | Suture | Fungus on the suture material itself | |
| | Incision | Fungus on skin in/around incision | |
| | Tail | Fungus on skin on the tail | |
| | Body | Fungus on skin on the body | |
| Organ Damage | 0 | No organ damage present | No signs of damage either due to the surgery or the presence of the tag. Tags can be adhered to organs as part of encapsulation process, but that does not constitute damage |
| | 1 | Some organ damage present | The suture captures, punctures, or entangles the pyloric caeca, stomach, spleen, or intestine |
| Peritoneal Apposition | 0 | Peritoneum completely closed, perfect apposition | |
| | 1 | Peritoneum partially closed | |
| | 2 | Peritoneum completely open (>75%) | |
| Signs of Expulsion | 0 | No signs of tag expulsion | No signs that the tag is being forced out through the incision or the lateral body wall; simple encapsulation may be present |
| | 1 | Some bulging or lateral pressure | Some evidence that the tag is causing pressure on the incision or the lateral body wall |
| | 2 | Expulsion process obvious or complete | The tag is obviously being forced out through the incision or the lateral body wall, or the tag is already out |

**Table 5. Names and descriptions of receivers and hydrophones used in the 2014 Chinook Salmon tagging study, with receiver codes used in Figure 9, the survival model (Figures 10 - 15), and in data processing by the United States Geological Survey (USGS). The release site was located at Durham Ferry. Average latitude and longitude are given for sites with multiple hydrophones.**

| Individual Receiver Name and Description | Hydrophone Location | | Receiver Code | Survival Model Code | Data Processing Code |
|---|---|---|---|---|---|
| | Latitude | Longitude | | | |
| San Joaquin River near Durham Ferry upstream of the release site, upstream | 37° 41.139'N | 121° 15.384'W | DFU1 | A0a | 300895 |
| San Joaquin River near Durham Ferry upstream of the release site, downstream | 37° 41.182'N | 121° 15.399'W | DFU2 | A0b | 300896 |
| San Joaquin River near Durham Ferry; release site (no acoustic hydrophone located here) | 37° 41.225'N | 121° 15.783'W | DF | A1 | |
| San Joaquin River near Durham Ferry downstream of the release site, upstream | 37° 41.316'N | 121° 16.562'W | DFD1 | A2a | 300894/460084 |
| San Joaquin River near Durham Ferry downstream of the release site, downstream | 37° 41.338'N | 121° 16.554'W | DFD2 | A2b | 460085 |
| San Joaquin River near Banta Carbona, upstream | 37° 43.658'N | 121° 17.924'W | BCAU | A3a | 300897 |
| San Joaquin River near Banta Carbona, downstream | 37° 43.700'N | 121° 17.912'W | BCAD | A3b | 460021 |
| San Joaquin River near Mossdale Bridge, upstream | 37° 47.505'N | 121° 18.419'W | MOSU | A4a | 300870 |
| San Joaquin River near Mossdale Bridge, downstream | 37° 47.552'N | 121° 18.408'W | MOSD | A4b | 300873 |
| San Joaquin River upstream of Head of Old River, upstream (not used in survival model) | 37° 48.347'N | 121° 19.122'W | HORU | B0a | 300872/455000 |
| San Joaquin River upstream of Head of Old River, downstream (not used in survival model) | 37° 48.336'N | 121° 19.192'W | HORD | B0b | 300871/450020 |
| San Joaquin River near Lathrop, upstream | 37° 48.666'N | 121° 19.176'W | SJLU | A5a | 450043/450044 |
| San Joaquin River near Lathrop, downstream | 37° 48.697'N | 121° 19.124'W | SJLD | A5b | 300880/300881 |
| Predator Removal Study Site 4 | 37° 49.116'N | 121° 19.050'W | RS4 | N1 | 301501/301502 |
| Predator Removal Study Site 5 | 37° 49.912'N | 121° 18.734'W | RS5 | N2 | 301503/301504 |
| Predator Removal Study Site 6 | 37° 51.082'N | 121° 19.331'W | RS6 | N3 | 301505/301506 |
| Predator Removal Study Site 7 | 37° 51.871'N | 121° 19.418'W | RS7 | N4 | 301507/301508 |
| Predator Removal Study Site 8 | 37° 53.266'N | 121° 19.813'W | RS8 | N5 | 301509/301510 |
| Predator Removal Study Site 9 | 37° 54.347'N | 121° 19.408'W | RS9 | N6 | 301511/301512 |

| | | | | | |
|---|---|---|---|---|---|
| Predator Removal Study Site 10 | 37° 55.087'N | 121° 19.235'W | RS10 | N7 | 300991 |
| San Joaquin River near Garwood Bridge, upstream | 37° 56.108'N | 121° 19.809'W | SJGU | A6a | 300879/450023 |

Table 5. (Continued)

| Individual Receiver Name and Description | Hydrophone Location | | Receiver Code | Survival | Data Processing |
|---|---|---|---|---|---|
| | Latitude | Longitude | | Model Code | Code |
| San Joaquin River near Garwood Bridge, downstream | 37° 56.119'N | 121° 19.828'W | SJGD | A6b | 300882/450045 |
| San Joaquin River at Stockton Navy Drive Bridge, upstream | 37° 56.798'N | 121° 20.393'W | SJNBU | A7a | 300884 |
| San Joaquin River at Stockton Navy Drive Bridge, downstream | 37° 56.806'N | 121° 20.365'W | SJNBD | A7b | 300906 |
| Burns Cutoff at Rough and Ready Island, upstream | 37° 56.412'N | 121° 21.064'W | RRIU | R1a | 300910 |
| Burns Cutoff at Rough and Ready Island, downstream | 37° 56.407'N | 121° 21.076'W | RRID | R1b | 300911 |
| San Joaquin River at MacDonald Island, upstream | 38° 01.012'N | 121° 27.692'W | MACU | A8a | 455008/455009 |
| San Joaquin River at MacDonald Island, downstream | 38°01.373'N | 121° 27.934'W | MACD | A8b | 455006/455007 |
| San Joaquin River near Medford Island, east | 38° 03.184'N | 121° 30.682'W | MFE | A9a | 300938/300940 |
| San Joaquin River near Medford Island, west | 38° 03.222'N | 121° 30.790'W | MFW | A9b | 300923/300930 |
| Old River East, near junction with San Joaquin, upstream | 37° 48.709'N | 121° 20.134'W | OREU | B1a | 300885/300886 |
| Old River East, near junction with San Joaquin, downstream | 37° 48.738'N | 121° 20.136'W | ORED | B1b | 450021/450022 |
| Old River South, upstream | 37° 49.232'N | 121° 22.657'W | ORSU | B2a | 300887 |
| Old River South, downstream | 37° 49.201'N | 121° 22.667'W | ORSD | B2b | 300889 |
| West Canal, upstream (not used in survival model) | 37° 50.784'N | 121° 33.573'W | WCLU | B3a | 300860 |
| West Canal, downstream (not used in survival model) | 37° 50.857'N | 121° 33.601'W | WCJLD | B3b | 300861 |
| Old River at Highway 4, upstream | 37° 53.632'N | 121° 34.026'W | OR4U | B4a | 300864/300865 |
| Old River at Highway 4, downstream | 37° 53.704'N | 121° 33.991'W | OR4D | B4b | 300875/300876 |
| Old River at the San Joaquin River mouth (not used in survival model) | 38° 4.272'N | 121° 34.538'W | OSJ | B5 | 300903/300905 |
| Middle River Head, upstream | 37° 49.470'N | 121° 22.766'W | MRHU | C1a | 300890 |
| Middle River Head, downstream | 37° 49.484'N | 121° 22.807'W | MRHD | C1b | 300892 |
| Middle River at Highway 4, upstream | 37° 53.768'N | 121° 29.583'W | MR4U | C2a | 300893/300899 |
| Middle River at Highway 4, downstream | 37° 53.807'N | 121 °29.594'W | MR4D | C2b | 300900/300901 |
| Middle River at Middle River (not used in survival model) | 38° 00.134'N | 121° 30.706'W | MID | C3 | 300942/300983 |
| Radial Gate at Clifton Court Forebay, upstream (in entrance channel to forebay), array 1 | 37° 49.802'N | 121° 33.397'W | RGU1 | D1a | 301162 |
| Radial Gate at Clifton Court Forebay, upstream, array 2 | 37° 49.784'N | 121° 33.481'W | RGU2 | D1b | 301163 |
| Radial Gate at Clifton Court Forebay, downstream (inside forebay), array 1 in | | | dual | | array |

| | | | | | |
|---|---|---|---|---|---|
| | 37° 49.812'N | 121° 33.454'W | RGD1 | D2a | 301161/460010 |

Table 5. (Continued)

| Individual Receiver Name and Description | Hydrophone Location | | Receiver Code | Survival Model Code | Data Processing Code |
|---|---|---|---|---|---|
| | Latitude | Longitude | | | |
| Radial Gate at Clifton Court Forebay, downstream, array 2 in dual array | 37° 49.812'N | 121° 33.454'W | RGD2 | D2b | 301160/460009 |
| Central Valley Project trashracks, upstream | 37° 49.012'N | 121° 33.507'W | CVPU | E1a | 460012/460023/301164 |
| Central Valley Project trashracks, downstream | 37° 48.999'N | 121° 33.537'W | CVPD | E1b | 301157 |
| Central Valley Project holding tank | 37° 48.951'N | 121° 33.548'W | CVPtank | E2 | 301159 |
| Turner Cut, east (closer to San Joaquin) | 37° 59.496'N | 121° 27.298'W | TCE | F1a | 000003/300915 |
| Turner Cut, west (farther from San Joaquin) | 37° 59.472'N | 121° 27.336'W | TCW | F1b | 300913/450024 |
| San Joaquin River at Jersey Point, east (upstream) | 38° 03.366'N | 121° 41.200'W | JPE | G1a | 300917,300918,300920-300922, 300924, 300928,300929 |
| San Joaquin River at Jersey Point, west (downstream) | 38° 03.322'N | 121° 41.294'W | JPW | G1b | 300931-300933,300936, 300937,300939, 300941,300943 |
| False River, west (closer to San Joaquin) | 38° 03.444'N | 121° 40.230'W | FRW | H1a | 300914/300916 |
| False River, east (farther from San Joaquin) | 38° 03.422'N | 121° 40.164'W | FRE | H1b | 300907/300912 |
| Chipps Island (aka Mallard Island), east (upstream) | 38° 02.922'N | 121° 55.834'W | MAE | G2a | 250456, 300908,300909, 300934, 300935,300979-300982,300985,300986 |
| Chipps Island (aka Mallard Island), west (downstream) | 38° 02.975'N | 121° 56.018'W | MAW | G2b | 300883,300888,300891, 300898,300902, 300904, 300989,300990,301153, 301154 |
| Benicia Bridge | 38° 02.440'N | 122° 07.409'W | BBR | G3 | 301486-30193 |
| Threemile Slough, south (not used in survival model) | 38° 06.454'N | 121° 41.041'W | TMS | T1a | 301165/301166 |
| Threemile Slough, north (not used in survival model) | 38° 06.681'N | 121° 40.992'W | TMN | T1b | 301155/301156 |
| Montezuma Slough, upstream (not used in survival model) | 38° 4.288'N | 121° 52.111'W | MZTU | T2a | 300877 |
| Montezuma Slough, downstream (not used in survival model) | 38° 4.288'N | 121° 52.181'W | MZTD | T2b | 300878 |
| Spoonbill Slough, upstream (not used in survival model) | 38° 3.315'N | 121° 53.718'W | SBSU | T3a | 300984 |
| Spoonbill Slough, downstream (not used in survival model) | 38° 3.328'N | 121° 53.733'W | SBSD | T3b | 301158 |

**Table 6. Environmental monitoring sites used in predator decision rule and route entrainment analysis for 2014 Chinook Salmon study. Database = CDEC (http://cdec.water.ca.gov/) or Water Library (http://www.water.ca.gov/waterdatalibrary/).**

| Environmental Monitoring Site | | | Detection Site | Data Available | | | | | Database |
|---|---|---|---|---|---|---|---|---|---|
| Site Name | Latitude (°N) | Longitude (°W) | | River Flow | Water Velocity | River Stage | Pumping | Reservoir Inflow | |
| BDT | 37.8650 | 121.3231 | RS6, RS7, RS8 | Yes | Yes | Yes | No | No | Water Library |
| CLC | 37.8298 | 121.5574 | RGU, RGD | No | No | No | No | Yes | CDEC |
| CSE | 38.0740 | 121.8501 | MTZ | No | No | Yes | No | No | CDEC |
| FAL | 38.0554 | 121.6672 | FRE/FRW | Yes | Yes | Yes | No | No | CDEC |
| GLC | 37.8201 | 121.4497 | ORS | No | No | Yes | No | No | Water Library |
| HLT | 38.0030 | 121.5108 | MID | Yes | Yes | Yes | No | No | CDEC |
| MAL | 38.0428 | 121.9201 | MTZ, SBS, MAE/MAW | No | Yes | Yes[b] | No | No | CDEC |
| MDB | 37.8908 | 121.4883 | MR4 | No | No | Yes | No | No | Water Library |
| MDM | 37.9425 | 121.5340 | MR4 | Yes | Yes | No | No | No | CDEC |
| MRU | 37.8339 | 121.3860 | MRH | Yes | Yes | No | No | No | Water Library |
| MRZ | 38.0276 | 122.1405 | BBR | No | No | Yes | No | No | CDEC |
| MSD | 37.7860 | 121.3060 | HOR, MOS | Yes | Yes | Yes | No | No | Water Library |
| OBI | 37.9694 | 121.5722 | OR4 | No | No | Yes | No | No | Water Library |
| ODM | 37.8101 | 121.5419 | CVP/CVPtank | Yes | Yes | Yes | No | No | CDEC[a] |
| OH1 | 37.8080 | 121.3290 | ORE | Yes | Yes | Yes | No | No | Water Library |
| OH4 | 37.8900 | 121.5697 | OR4 | Yes | Yes | No | No | No | CDEC |
| ORX | 37.8110 | 121.3866 | ORS | Yes | Yes | No | No | No | Water Library |
| OSJ | 38.0711 | 121.5789 | OSJ | Yes | Yes | Yes | No | No | CDEC |
| PRI | 38.0593 | 121.5575 | MAC, MFE/MFW | Yes | Yes | Yes | No | No | CDEC |
| RMID040 | 37.8350 | 121.3838 | MRH | No | No | Yes | No | No | Water Library |
| ROLD040 | 37.8286 | 121.5531 | RGU, RGD, WCL | No | No | Yes | No | No | Water Library |
| SJG | 37.9351 | 121.3295 | RS9, RS10, SJG, SJNB, RRI | Yes | Yes | Yes | No | No | CDEC |
| SJJ | 38.0520 | 121.6891 | JPE/JPW | Yes | Yes | Yes | No | No | CDEC |
| SJL | 37.8100 | 121.3230 | SJL, RS4, RS5 | No | No | Yes | No | No | Water Library |

[a] = California Water Library was used for river stage.

[b] = Used for river stage for SBS and MAE/MAW.

**Table 6. (Continued)**

| Environmental Monitoring Site | | | Detection Site | Data Available | | | | | Database |
|---|---|---|---|---|---|---|---|---|---|
| Site Name | Latitude (°N) | Longitude (°W) | | River Flow | Water Velocity | River Stage | Pumping | Reservoir Inflow | |
| TRN | 37.9927 | 121.4541 | TCE/TCW | Yes | Yes | Yes | No | No | CDEC |
| TRP | 37.8165 | 121.5596 | CVP/CVPtank | No | No | No | Yes | No | CDEC |
| TSJ | 38.0900 | 121.6869 | TMS/TMN | No | No | Yes | No | No | Water Library |
| TSL | 38.1004 | 121.6866 | TMS/TMN | Yes | Yes | No | No | No | CDEC |
| VNS | 37.6670 | 121.2670 | DFU, DFD, BCA | Yes | No | Yes | No | No | CDEC |
| WCI | 37.8316 | 121.5541 | RGU, RGD, WCL | Yes | Yes | No | No | No | Water Library |

[a] = California Water Library was used for river stage.

[b] = Used for river stage for SBS and MAE/MAW.

**Table 7a. Cutoff values used in predator filter in 2014. Observed values past cutoff or unmet conditions indicate a predator. Time durations are in hours unless otherwise specified. See Table 7b for Flow, Water Velocity, Extra Conditions, and Comment. Footnotes refer to both this table and Table 7b.**

| Detection Site | Previous Site | Residence Time[a] (h) | | | Migration Rate[b, c] (km/h) | | Time since last visit (h) | BLPS (Absolute value) | No. of Visits | No. of Cumulative Upstream Forays |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Near Field | Mid-field | Far-field | | | | | | |
| | | Maximum | Maximum | Maximum | Minimum | Maximum | Maximum | Maximum | Maximum | Maximum |
| DFU | DF, DFD | 1 | 2 | 15 | 0.2 (0.8[f]) | 4 | | | 1 | 1 |
| | DFU | 1 | 3 | 15 | | | | | 2 | 0 |
| DFD | DF, DFU | 4 | 8 | 15 | 0.3 (0.05[f]) | 4 | | | 1 | 0 |
| | DFD | 2 | 35 | 70 | | | | | 2 | 0 |
| | BCA | 2 | 4 | 15 | 0.1 | 4 | | | 0 | 0 |
| BCA | DF, DFU, DFD | 10 | 20 | 40 | 0.1 | 4 | | | 1 | 0 |
| | BCA | 0.2 | 45 | 90 | | | | | 2 | 0 |
| | MOS | 0.2 | 0.2 | 40 | 0.1 | 4 | | | 0 | 0 |
| MOS | DF, DFD, BCA | 12 | 24 | 60 | 0.1 | 5.5 | | 8 | 1 | 0 |
| | MOS | 2 | 51 | 102 | | | | | 2 | 1 |
| | HOR | 2 | 4 | 60 | 0.1 | 5.5 | | 8 | 2 | 1 |
| SJL | HOR, MOS | 10 | 25 | 50 | 0.1 | 5.5 | 15 | 8 | 2 | 0 |
| | SJL | 1 | 51 | 102 | | | | | 2 | 1 |
| | RS4 | 1 | 10 | 159 (20[e]) | 0.1 | 4 | 15 | 8 | 3 | 1 |
| RS4 | SJL, HOR | 5 | 15 | 133 (150[f]) | 0.1 | 5.5 | 15 | 8 | 2 | 0 |
| | RS4 | 1 | 41 | 211 | | | | | 2 | 1 |
| | RS5 | 1 | 10 | 282 (20[e]) | 0.1 | 4 | 15 | 8 | 3 | 1 |
| RS5 | RS4 | 5 | 15 | 249 | 0.1 | 5.5 | 15 | 8 | 2 | 0 |
| | RS5 | 1 | 41 | 310 | | | | | 2 | 1 |
| | RS6 | 0.5 | 10 | 360 (20[e]) | 0.1 | 4 | 15 | 8 | 3 | 1 |
| RS6 | RS5 | 10 | 25 | 360 | 0.1 | 5.5 | 15 | 8 | 2 | 0 |

a = Near field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere; far-field residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate was calculated on most direct pathway.

c = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions."

e = Condition at departure from previous site.

f = See comments for alternative criteria.

**Table 7a. (Continued)**

| Detection Site | Previous Site | Residence Time[a] (h) Near Field | Mid-field | Far-field | Migration Rate[b, c] (km/h) | | Time since last visit (h) | BLPS (Absolute value) | No. of Visits | No. of Cumulative Upstream Forays |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Maximum | Maximum | Maximum | Minimum | Maximum | Maximum | Maximum | Maximum | Maximum |
| RS6 | RS6 | 1 | 51 | 102 (360[f]) | | | | | 2 | 1 |
| | RS7 | 0.5 | 10 | 360 (20[e]) | 0.1 | 4 | 15 | 8 | 3 | 1 |
| RS7 | HOR, RS6 | 10 | 25 | 360 | 0.1 | 5.5 | 15 | 8 | 2 | 0 |
| | RS7 | 1 | 51 | 360 | | | | | 2 | 1 |
| | RS8 | 0.5 | 10 | 360 (20[e]) | 0.1 | 4 | 15 | 8 | 3 | 1 |
| RS8 | RS7 | 10 | 25 | 360 | 0.1 | 5.5 | 15 | 8 | 2 | 0 |
| | RS8 | 1 | 51 | 360 | | | | | 2 | 1 |
| | RS9 | 0.5 | 10 | 360 | 0.1 | 4 | 15 | 8 | 3 | 1 |
| RS9 | RS8 | 5 | 15 | 360 | 0.1 | 5.5 | 15 | 8 | 2 | 0 |
| | RS9 | 1 | 41 | 360 | | | | | 2 | 1 |
| | RS10 | 0.5 | 10 | 360 | 0.1 | 4 | 15 | 8 | 3 | 1 |
| RS10 | RS9 | 5 | 15 | 360 | 0.1 | 5.5 | 15 | 8 | 2 | 0 |
| | RS10 | 1 | 41 | 360 | | | | | 2 | 1 |
| | SJG | 0.5 | 10 | 360 | 0.1 | 4 | 15 | 8 | 3 | 1 |
| SJG | RS9, RS10 | 12 | 24 | 360 | 0.1 | 5.5 | 15 | 8 | 1 | 0 |
| | SJG | 1 | 42 | 360 | | | | | 2 | 1 |
| | SJNB | 3 | 6 | 360 | 0.1 | 4 | 15 | 8 | 2 | 2 |
| SJNB | SJG | 15 (6[f]) | 30 (12[f]) | 360 | 0.1 | 5.5 | 15 | 8 | 2 | 0 |
| | SJNB | 1 | 50 | 360 | | | | | 2 | 3 |
| | RRI | 1 | 2 | 360 | 0.5 | 1 | 15 | | 2 | 0 |
| RRI | SJG | 15 | 30 | 360 | 0.1 | 5.5 | 15 | 8 | 1 | 0 |

a = Near field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere; far-field residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate was calculated on most direct pathway.

c = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions."

e = Condition at departure from previous site.

f = See comments for alternative criteria.

Table 7a. (Continued)

| Detection Site | Previous Site | Residence Time[a] (h) | | | Migration Rate[b, c] (km/h) | | Time since last visit (h) | BLPS (Absolute value) | No. of Visits | No. of Cumulative Upstream Forays |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Near Field | Mid-field | Far-field | | | | | | |
| | | Maximum | Maximum | Maximum | Minimum | Maximum | Maximum | Maximum | Maximum | Maximum |
| RRI | RRI | 1 | 48 | 360 | | | | | 2 | 3 |
| | SJNB | 1 | 2 | 360 | 0.5 | 1 | 15 | | 2 | 0 |
| MAC | SJNB | 30 (20[f]) | 60 (40[f]) | 120 (80[f]) | 0.1 (0.3[f]) | 5.5 | 24 | 8 | 1 | 0 |
| | MAC | 30 | 119 | 238 | | | | | 2 | 3 |
| TCE/TCW | SJNB | 12 | 24 | 48 | 0.1 | 5.5 | 24 | 8 | 1 | 0 |
| | TCE/TCW | 1 | 54 | 108 | | | | | 2 | 3 |
| | MAC | 1 | 2 | 276 | 0.1 | 5.5 | 24 | 8 | 2 | 3 |
| MFE/MFW | MAC | 30 (20[f]) | 60 (40[f]) | 120 (80[f]) | 0.1 (0.3[f]) | 5.5 | 36 | 8 | 2 | 0 |
| | OSJ | 1 | 2 | 24 | 1 | 1 | 36 | 8 | 2 | 3 |
| HOR | DF, MOS | 16 | 32 | 60 | 0.1 | 5.5 | | 8 | 1 (2[f]) | 0 |
| | HOR | 3 | 60 | 120 | | | | | 2 | 1 |
| | SJL | 3 (4[f]) | 6 (8[f]) | 60 (10[e]) | 0.1 | 5.5 (6[f]) | 15 | 8 | 2 | 1 |
| ORE | HOR | 10 | 20 | 40 | 0.1 | 5.5 | 15 | 8 | 1 | 0 |
| | ORE | 1 | 46 | 92 | | | | | 2 | 1 |
| ORS | ORE | 15 | 30 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 0 |
| | ORS | 5 | 64 | 128 | | | | | 2 | 1 |
| | MRH | 1 | 2 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 1 |
| WCL | ORS | 10 | 20 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 0 |
| | RGU/RGD | 10 | 20 | 360 | 0.1 | 5.5 | 36 | 8 | 3 | 3 |
| | OR4, MR4 | 10 | 20 | 360 | 0.1 | 5.5 | 36 | 8 | 2 | 3 |
| OR4 | WCL | 20 | 40 | 360 | 0.1 | 5.5 | 36 | 8 | 2 | 0 |

a = Near field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere; far-field residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate was calculated on most direct pathway.

c = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions."

e = Condition at departure from previous site.

f = See comments for alternative criteria.

**Table 7a. (Continued)**

| Detection Site | Previous Site | Residence Time[a] (h) | | | Migration Rate[b, c] (km/h) | | Time since last visit (h) | BLPS (Absolute value) | No. of Visits | No. of Cumulative Upstream Forays |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Near Field | Mid-field | Far-field | | | | | | |
| | | Maximum | Maximum | Maximum | Minimum | Maximum | Maximum | Maximum | Maximum | Maximum |
| OR4 | MR4 | 20 | 40 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 3 |
| | TCE/TCW | 20 | 40 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 3 |
| OSJ | MAC, OR4, MFE/MFW, TCE/TCW, MID, | 2 | 4 | 8 | 0.1 | 5.5 | 36 | 8 | 1 | 0 |
| | OSJ | 1 | 22 | 44 | | | | | 2 | 3 |
| | FRE/FRW | 1 | 2 | 8 | 1 | 2 | 36 | 8 | 1 | 3 |
| MRH | ORE | 6 | 12 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 0 |
| | MRH | 1 | 42 | 84 | | | | | 2 | 1 |
| | ORS | 1 | 2 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 0 |
| MR4 | TCE/TCW | 10 | 20 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 0 |
| MID | MAC, TCE/TCW | 20 | 40 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 0 |
| | OSJ | 20 | 40 | 360 | 0.1 | 5.5 | | 8 | 1 | 3 |
| | MID | 1 | 70 | 360 | | | 36 | | 2 | 3 |
| RGU/RGD | ORS | 24 (40[h]; 80[i]) | | 360 | 0.1 | 5.5 | | 8 | 1 | 0 |
| | CVP | 24 (40[h]; 80[i]) | | 360 | 0.1 | 5.5 | | 8 | 2 | 0 |
| | WCL | 24 (40[h]; 80[i]) | | 360 | 0.1 | 5.5 | | 8 | 2 | 3 |
| CVP | ORS | 20 | 40 | 360 | 0.1 | 5.5 | 36 | 8 | 1 | 0 |
| | CVP | 10 | 79 | 360 | | | | | 3 | 3 |
| | RGU/RGD | 10 | 20 | 360 | 0.2 | 5.5 | 36 | 8 | 2 (1[f]) | 3 (2[f]) |
| CVPtank | CVP | 20 | 150 | 360 | | | | | 2 | 3 |

a = Near field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere; far-field residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate was calculated on most direct pathway.

c = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions."

f = See comments for alternative criteria.

h = If returned to Forebay entrance channel from Clifton Court Forebay and most detections were at RGU (not RGD).

i = If known presence at gates < 24 hours, or if present at RGU < 80% of total residence time before returning to Forebay entrance channel.

**Table 7a. (Continued)**

| Detection Site | Previous Site | Residence Time[a] (h) Near Field | Mid-field | Far-field | Migration Rate[b, c] (km/h) | | Time since last visit (h) | BLPS (Absolute value) | No. of Visits | No. of Cumulative Upstream Forays |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Maximum | Maximum | Maximum | Minimum | Maximum | Maximum | Maximum | Maximum | Maximum |
| JPE/JPW | OSJ, MFE/MFW, MAC, TCE/TCW | 40 | 80 | 160 | 0.1 | 5.5 | 30 | 8 | 1 | 0 |
| | FRE/FRW | 30 | 112 | 360 | 0.1 | 5.5 | 30 | | 3 | 3 |
| | JPE/JPW | 30 | 112 | 360 | | | | | 3 | 0 |
| | SBS, BBR | 0.1 | 0.2 | 360 | 1 | 4 | 30 | 8 | 2 | 3 |
| FRE/FRW | OSJ, MAC, TCE/TCW | 30 | 80 | 160 | 0.1 | 5.5 | 30 | 8 | 1 | 0 |
| | FRE/FRW | 10 | 94 | 360 | | | | | 3 | 0 |
| | JPE/JPW | 30 | 114 | 360 | 0.1 | 5.5 | | | 3 | 3 |
| TMN/TMS | MFE/MFW | 6 | 12 | 360 | 0.2 | 4.5 | 30 | 8 | 1 | 0 |
| | TMN/TMS | 3 | 49 | 360 | | | | | 2 | 0 |
| | JPE/JPW, BBR | 6 | 12 | 360 | 0.2 | 4.5 | 30 | 8 | 2 (1[f]) | 3 |
| MTZ | JPE/JPW, TMN/TMS | 1 | 2 | 360 | 0.1 | 5.5 | 30 | 8 | 1 | 0 |
| | MTZ | 1 | 33 | 360 | | | | | 2 | 0 |
| | SBS, MAE/MAW | 1 | 2 | 360 | 0.1 | 5.5 | 30 | 8 | 2 (1[f]) | 3 |
| SBS | JPE/JPW | 1 | 2 | 360 | 0.1 | 5.5 | 30 | 8 | 1 | 0 |
| | MAE/MAW | 1 | 2 | 360 | 0.1 | 5.5 | 30 | 8 | 2 | 3 |

a = Near field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere; far-field residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate was calculated on most direct pathway.

c = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions."

f = See comments for alternative criteria.

**Table 7a. (Continued)**

| Detection Site | Previous Site | Residence Time[a] (h) | | | Migration Rate[b, c] (km/h) | | Time since last visit (h) | BLPS (Absolute value) | No. of Visits | No. of Cumulative Upstream Forays |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Near Field | Mid-field | Far-field | | | | | | |
| | | Maximum | Maximum | Maximum | Minimum | Maximum | Maximum | Maximum | Maximum | Maximum |
| MAE/MAW | CVPtank, MFE/MFW, TMN/TMS, JPE/JPW | 40 | 200 | 360 | 0.1 | 5.5 | | 8 | 1 (2[f]) | 0 |
| | MTZ | 40 | 200 | 360 | 0.1 | 5.5 | | 8 | 2 | 0 |
| | MAE/MAW | 10 | 50 | 360 | | | | | 2 | 0 |
| | BBR | 5 | 25 | 360 | 0.1 | 5.5 | | 8 | 2 | 3 |
| BBR | CVPtank, MTZ, MAE/MAW | 25 | 125 | 360 | 0.1 | 5.5 | | 8 | 1 | 0 |

a = Near field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere; far-field residence time includes all time from entry in region to arrival at and departure from current site.

b = Approximate migration rate was calculated on most direct pathway.

c = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions."

f = See comments for alternative criteria.

**Table 7b. Cutoff values used in predator filter in 2014. Observed values past cutoff or unmet conditions indicate a predator. Time durations are in hours unless otherwise specified. Footnotes, Extra Conditions and Comment refer to both this table and Table 7a.**

| Detection Site | Previous Site | Flow[d] (cfs) | | Water Velocity[d] (ft/s) | | | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| | | At arrival | At departure[e] | At arrival | At departure[e] | Average during transition | | |
| DFU | DF, DFD | | | | | | | Alternate value if coming from DFD |
| | DFU | | | | | | Travel time < 20 | |
| DFD | DF, DFU | | | | | | | |
| | DFD | | | | | | Travel time < 20 | |
| | BCA | | | | | | Not allowed | |
| BCA | DF, DFU, DFD | | | | | | | |
| | BCA | | | | | | Travel time < 20 | |
| | MOS | | | | | | Not allowed | |
| MOS | DF, DFD, BCA | | | | | | | |
| | MOS | < 14,000 | | | | < 2.7 | Travel time < 20 | |
| | HOR | < 14,000 | | | | < 0.1 | | |
| SJL | HOR, MOS | | | | | | | |
| | SJL | | | | | | Travel time < 20 | |
| | RS4 | | | | | | Next transition must be directed downstream | |
| RS4 | SJL, HOR | | | | | | | Alternate value if coming from HOR |
| | RS4 | | | | | | Travel time < 20 | |
| | RS5 | | | | | | Next transition must be directed downstream | |
| RS5 | RS4 | | | | | | | |
| | RS5 | | | | | | Travel time < 20 | |
| | RS6 | | | | | | Next transition must be directed downstream | |
| RS6 | RS5 | | | | | | | |

d = Classified as predator if flow or velocity condition, if any, is violated.

e = Condition at departure from previous site.

**Table 7b. (Continued)**

| Detection Site | Previous Site | Flow[d] (cfs) At arrival | Flow[d] (cfs) At departure[e] | Water Velocity[d] (ft/s) At arrival | Water Velocity[d] (ft/s) At departure[e] | Water Velocity[d] (ft/s) Average during transition | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| RS6 | RS6 | | | | | > 1.9 | Travel time < 20<br>Next transition must be | Alternate values if average transition water velocity outside range |
| | RS7 | | | | | | directed downstream | |
| RS7 | HOR, RS6 | | | | | | | |
| | RS7 | | | | | | Travel time < 20 | |
| | RS8 | | | | | < 1.3 | Next transition must be directed downstream | |
| RS8 | RS7 | | | | | | | |
| | RS8 | | | | | | Travel time < 20 | |
| | RS9 | | | | | < 1.3 | Next transition must be directed downstream | |
| RS9 | RS8 | | | | | | | |
| | RS9 | | | | | | Travel time < 20 | |
| | RS10 | | | | | < 1.3 | Next transition must be directed downstream | |
| RS10 | RS9 | | | | | | | |
| | RS10 | | | | | | Travel time < 20 | |
| | SJG | | | | | < 1.3 | Next transition must be directed downstream | |
| SJG | RS9, RS10 | | | | | | | |
| | SJG | | | | | | Not allowed | SJNB SJG |
| | SJNB | < 3500 | < 3500 | < 1.1 | < 1.1 | < 0.5 | | < 2 (> 2[f])<br>d<br>= |

Classified as predator if flow or velocity condition, if any, is violated. e = Condition at departure from previous site.

f = See comments for alternative criteria.

Alternate values for change in river stage at arrival: < -0.1 or > 0.1

**Table 7b. (Continued)**

| Detection Site | Previous Site | Flow[d] (cfs) At arrival | Flow[d] (cfs) At departure[e] | Water Velocity[d] (ft/s) At arrival | Water Velocity[d] (ft/s) At departure[e] | Water Velocity[d] (ft/s) Average during transition | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| SJNB | SJNB | < 600 (> -250)[g] | > -250 (< 600)[g] | < 0.2 (> -0.1)[g] | > -0.1 (< 0.2)[g] | < 1.5 | Travel time < 14 | |
| | RRI | | | | | | | |
| RRI | SJG | | | | | | | |
| | RRI | < 600 (> -250)[g] | > -250 (< 600)[g] | < 0.2 (> -0.1)[g] | > -0.1 (< 0.2)[g] | < 1.5 | Not allowed | |
| | SJNB | | | | | | | |
| MAC | SJNB | | | | | -0.1 to 0.4 | | Alternate values if average transition water velocity outside range |
| | MAC | | | < 0.2 (> -0.1)[g] | > -0.1 (< 0.2)[g] | | | |
| TCE/TCW | SJNB | < 1200 | | < 0.1 | | | | |
| | TCE/TCW | < 500 (> 500)[g] | > 500 (< 500)[g] | < 0.1 (> 0.1)[g] | > 0.1 (< 0.1)[g] | -0.2 to 0.2 | | |
| | MAC | < 1200 | | < 0.1 | < 0.2 | | | |
| MFE/MFW | MAC | | | | | -0.1 to 0.4 | | Alternate values if average transition water velocity outside range |
| | OSJ | | | | | | | |
| HOR | DF, MOS | | | | | | | Alternate value if coming from MOS |
| | HOR | < 14,000 | | | | | Travel time < 20 | |
| | SJL | < 14,000 | | < 2 | < 2 | < 1 (1.3[f]) | | Alternate value if next transition is downstream |
| ORE | HOR | | | | | | | |
| | ORE | | | | | | Travel time < 20 | |
| ORS | ORE | > -2500 | | > -0.5 | | | | |
| | ORS | < 2500 (> -2500)[g] | > -2500 (< 2500)[g] | < 0.5 (> -0.5)[g] | > -0.5 (< 0.5)[g] | | | |

d = Classified as predator if flow or velocity condition, if any, is violated.

e = Condition at departure from previous site.

f = See comments for alternative criteria.

g = High flow/velocity on departure requires low values on arrival (and vice versa).

**Table 7b. (Continued)**

| Detection Site | Previous Site | Flow[d] (cfs) At arrival | Flow[d] (cfs) At departure[e] | Water Velocity[d] (ft/s) At arrival | Water Velocity[d] (ft/s) At departure[e] | Water Velocity[d] (ft/s) Average during transition | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| ORS | MRH | | | | | | | |
| WCL | ORS | > -1500 | | > -0.5 | | | | |
| | RGU/RGD | > -1500 | | > -0.5 | | | CCFB inflow < 3000 cfs on departure[e] | |
| | OR4, MR4 | < 1500 | < 1500 | < 0.5 | < 0.5 | | | |
| OR4 | WCL | > -1500 | | > -0.5 | | | | |
| | MR4 | | | | | | | |
| | TCE/TCW | | < 500 | | < 0.1 | | | |
| OSJ | MAC, MFE/MFW, TCE/TCW, MID, OR4 | | | | | | | |
| | OSJ | | | | | | Not allowed | |
| | FRE/FRW | | | | | | | |
| MRH | ORE | | | | | | | |
| | MRH | | | | | | | |
| | ORS | | | | | | | |
| MR4 | TCE/TCW | | | < 0.15 | < 0.1 | | | |
| MID | MAC, TCE/TCW | | | | | | | |
| | OSJ | < 1500 | | < 0.1 | | | | |
| | MID | < 1500 (> -1500)[g] | > -1500 (< 1500)[g] | < 0.1 (> -0.1)[g] | > -0.1 (< 0.1)[g] | | | |
| RGU/RGD | ORS | | | | | | | |
| | CVP | | > -1500 | | > -1.0 | | CVP pumping < 1500 cfs on departure[e] | |
| | WCL | | < 2000 | | < 0.8 | | | |

d = Classified as predator if flow or velocity condition, if any, is violated.

e = Condition at departure from previous site.

g = High flow/velocity on departure requires low values on arrival (and vice versa).

**Table 7b. (Continued)**

| Detection Site | Previous Site | Flow[d] (cfs) At arrival | Flow[d] (cfs) At departure[e] | Water Velocity[d] (ft/s) At arrival | Water Velocity[d] (ft/s) At departure[e] | Water Velocity[d] (ft/s) Average during transition | Extra Conditions | Comment |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CVP | ORS | | | | | | | Transition from BCA not allowed |
| | CVP | | | | | | CVP pumping > 800 cfs on arrival, < 850 cfs on departure | |
| | RGU/RGD | < 3000 | | < 1.5 | | | | Alternate values if came from lower SJR |
| CVPtank | CVP | | | | | | Travel time < 100 | |
| JPE/JPW | OSJ, MAC, MFE/MFW, TCE/TCW | | | | | | | |
| | FRE/FRW | | | | | | | |
| | JPE/JPW | | | | | | Travel time < 50 | |
| | SBS, BBR | | | | | | | |
| FRE/FRW | OSJ, MAC, TCE/TCW | | | | | | | |
| | FRE/FRW | | | | | | | |
| | JPE/JPW | | | | | | | |
| TMN/TMS | MFE/MFW | | > -50,000 | | > -1 | | | |
| | TMN/TMS | < 0 (> -0)[g] | > -0 (< 0)[g] | < 0 (> -0)[g] | > -0 (< 0)[g] | | | |
| | JPE/JPW, BBR | | | | | | | Alternate values if coming from BBR |
| MTZ | JPE/JPW, TMN/TMS | | | | | | | |
| | MTZ | | | | | | Travel time < 20 | |
| | SBS, MAE/MAW | | | | | | | Alternate values if coming from MAE/MAW |
| SBS | JPE/JPW | | | | | | | |
| | MAE/MAW | | | | | | | |

d = Classified as predator if flow or velocity condition, if any, is violated.

e = Condition at departure from previous site.

g = High flow/velocity on departure requires low values on arrival (and vice versa).

**Table 7b. (Continued)**

| Detection Site | Previous Site | Flow[d] (cfs) | | Water Velocity[d] (ft/s) | | | Extra Conditions | Comment |
|---|---|---|---|---|---|---|---|---|
| | | At arrival | At departure[e] | At arrival | At departure[e] | Average during transition | | |
| MAE/MAW | CVPtank, MFE/MFW, TMN/TMS, JPE/JPW | | | > -0.2 | | | Upstream foray < 25 km | Alternate values if coming from JPE/JPW |
| | MTZ | | | | | | Upstream foray < 25 km | |
| | MAE/MAW | | | | | | | |
| | BBR | | | | | | Upstream foray < 25 km | |
| BBR | CVPtank, MTZ, MAE/MAW | | | > -0.2 | | | Upstream foray < 25 km | |
| | BBR | | | | | | | |

d = Classified as predator if flow or velocity condition, if any, is violated.

e = Condition at departure from previous site.

**Table 8: Daily QA/QC results measuring water temperature in the raceway, anesthesia bucket, and gravity feed and the difference between the 1) raceway and anesthesia bucket and 2) the raceway and gravity feed, and 3) the raceway and the recovery bucket, both pre and post surgery. Dissolved oxygen (DO) was measured in recovery buckets before and after surgery and the difference was identified between the DO in the raceway and DO in the recovery buckets pre and post surgery. Measurements outside of criteria are highlighted in red.**

| Date | Time | Raceway Temp (°C) | Anesthesia Bucket Temp (°C) | Diff in (°C) between anesthesia bucket and raceway | Gravity Feed Temp (°C) | Diff in (°C) between Gravity feed and raceway | Recovery Bucket DO (%) | | Recovery Bucket Temp (°C) | | Diff between Recovery Bucket and raceway (°C) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pre | Post | Pre | Post | Pre | Post |
| 4/15/2014 | ----- | 13.4 | 14.8 | 1.4 | 14.7 | 1.3 | 139.7 | 129.6 | 14.2 | 14.6 | 0.8 | 1.2 |
| 4/16/2014 | ----- | 13.3 | 13.3 | 0.0 | 16.5 | 3.2 | 142.4 | 133.5 | 14.6 | 15.1 | 1.3 | 1.8 |
| 4/17/2014 | ----- | 13.6 | 13.8 | 0.2 | 15.2 | 1.6 | 146.8 | 150.8 | 14.7 | 14.3 | 1.1 | 0.7 |
| 4/18/2014 | 1220 | 13.5 | ----- | ----- | 15.5 | 2.0 | 135.2 | 121.7 | 13.8 | 14.2 | 0.3 | 0.7 |
| 4/29/2014 | 1315 | 13.9 | 15.2 | 1.3 | 15.6 | 1.7 | 165.3 | 152.2 | 14.1 | 14.5 | 0.2 | 0.6 |
| 4/30/2014 | 0948 | 13.4 | 14.0 | 0.6 | 15.9 | 2.5 | 124.0 | 140.5 | 14.2 | 14.1 | 0.8 | 0.7 |
| 5/1/2014 | ----- | 14.2 | 15.8 | 1.6 | 16.6 | 2.4 | 137.7 | 144.9 | 15.4 | 15.9 | 1.2 | 1.7 |
| 5/2/2014 | 0931 | 13.4 | 13.9 | 0.5 | 14.6 | 1.2 | 139.6 | 140.5 | 13.9 | 14.2 | 0.5 | 0.8 |
| 5/14/2014 | 1315 | 14.6 | 16.1 | 1.5 | 16.4 | 1.8 | 153 | 127.4 | 16.6 | 16.3 | 2.0 | 1.7 |
| 5/15/2014 | 1008 | 14.2 | 14.6 | 0.4 | 14.8 | 0.6 | 131.2 | 122.8 | 15.0 | 15.0 | 0.8 | 0.8 |
| 5/16/2014 | ----- | 14.5 | 16.1 | 1.6 | 16.5 | 2.0 | 148.6 | 141.5 | 15.4 | 15.6 | 0.9 | 1.1 |
| 5/17/2014 | ----- | 14.2 | 14.9 | 0.7 | 14.7 | 0.5 | 139.2 | 125.1 | 14.6 | 14.8 | 0.4 | 0.6 |
| Average | | 14.0 | 14.9 | 0.9 | 15.6 | 1.6 | 142.1 | 136.7 | 14.8 | 14.9 | 0.8 | 0.9 |
| SD | | 0.45 | 0.93 | 0.56 | 0.76 | 0.68 | 11.78 | 11.53 | 0.86 | 0.79 | 0.53 | 0.42 |

**Table 9. Results of dummy-tagged Chinook Salmon after being held for 48 h at the release site as part of Salmon Survival Study in 2014. All fish were held at Durham Ferry.**

| Examination Date, Time | Mean (SD) Fork Length (mm) | Mortality | Mean (SD) Scale Loss (%) | Normal Body Color | No Fin Hemorrhaging | Normal Eye Quality | Normal Gill Color |
|---|---|---|---|---|---|---|---|
| 4/17/14, 1435 | 96.5 (4.9) | 0/15 | 3.7 (3.0) | 15/15 | 15/15 | 14/15 | 9/15 |
| 4/18/14, 1415 | 94.6 (5.6) | 0/15 | 6.3 (3.0) | 9/15 | 15/15 | 15/15 | 7/15 |
| 4/19/14, 1315 | | 0/30* | | | | | |
| 4/20/14, 1317 | 96.1 (4.4) | 0/15 | 5.0 (2.7) | 13/15 | 15/15 | 15/15 | 10/15 |
| 5/1/14, 1329 | 98.6 (4.8) | 0/15 | 3.7 (3.0) | 15/15 | 15/15 | 15/15 | 14/15 |
| 5/2/14, 1413 | 99.0 (5.7 | 0/15 | 6.0 (3.4) | 15/15 | 14/15 | 15/15 | 14/15 |
| 5/3/14, 1328 | 97.9 (5.0) | 0/15 | 7.7 (3.7) | 15/15 | 15/15 | 15/15 | 15/15 |
| 5/4/14, 1315 | | 0/30* | | | | | |
| 5/16/14, 1325** | 93.3 (3.1) | 0/14 | 5.4 (2.4) | 14/14 | 14/14 | 14/14 | 14/14 |
| 5/17/14, 1338** | 95.6 (3.6) | 0/14 | 7.1 (4.3) | 14/14 | 14/14 | 14/14 | 14/14 |
| 5/18/14, 1320 | 97.7 (4.7) | 0/15 | 9.0 (3.4) | 15/15 | 15/15 | 15/15 | 15/15 |
| 5/19/14, 1315 | | 0/30* | | | | | |

*Fish given to CA/NV Fish Health Center for further evaluation

**Only 14 fish in can; only 14 fish assessed.

**Table 10: Scoring matrix and results of scoring surgical implantation for dummy-tagged fish held at the release site for 48 h.**

| SCORING POTENTIAL | SUTURE PRESENT? ANT | POST | INCISION APPOSITION | FUNGUS | ORGAN DAMAGE | PERITONEAL APPOSITION | SIGNS OF EXPULSION | COMPOSITE SCORE |
|---|---|---|---|---|---|---|---|---|
| MIN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MID | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 6 |
| MAX | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 12 |
| Date/Time | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) |
| 4/17/14, 1435 | 0.1 (0.3) | 0.1 (0.3) | 0.2 (0.4) | 0 (0) | 0.6 (0.5) | 1.2 (0.7) | 0 (0) | 2.0 (1.0) |
| 4/18/14, 1415 | 0 (0) | 0 (0) | 0.1 (0.4) | 0 (0) | 0.5 (0.5) | 0.7 (0.6) | 0 (0) | 1.4 (1.0) |
| 4/19/14, 1315 | * | * | * | * | * | * | * | * |
| 4/20/14, 1317 | 0.1 (0.3) | 0 (0) | 0.1 (0.3) | 0 (0) | 0.5 (0.5) | 0.8 (0.7) | 0 (0) | 1.3 (0.9) |
| 5/1/14, 1329 | 0 (0) | 0 (0) | 0.5 (0.5) | 0.4 (0.5) | 1.1 (0.8) | 0.8 (0.4) | 0 (0) | 2.8 (1.0) |
| 5/2/14, 1413 | 0.1 (0.3) | 0.1 (0.4) | 0.7 (0.7) | 0 (0) | 0.6 (0.5) | 0.6 (0.5) | 0 (0) | 2.1 (1.4) |
| 5/3/14, 1328 | 0.1 (0.3) | 0 (0) | 0.9 (0.7) | 0 (0) | 0.5 (0.6) | 0.7 (0.5) | 0 (0) | 2.1 (1.3) |
| 5/4/14, 1315 | * | * | * | * | * | * | * | * |
| 5/16/14, 1325** | 0 (0) | 0 (0) | 0.4 (0.8) | 0 (0) | 0.2 (0.4) | 0.9 (0.5) | 0 (0) | 1.6 (0.9) |
| 5/17/14, 1338** | 0 (0) | 0 (0) | 0.5 (0.7) | 0 (0) | 0.6 (0.6) | 0.9 (0.4) | 0 (0) | 1.9 (1.1) |
| 5/18/14, 1320 | 0.1 (0.3) | 0.1 (0.3) | 0.5 (0.7) | 0 (0) | 0.3 (0.6) | 0.9 (0.4) | 0 (0) | 1.8 (0.9) |
| 5/19/14, 1315 | * | * | * | * | * | * | * | * |

*Fish given to CA/NV Fish Health Center for fish health evaluation

**Only 14 fish in can

**Table 11. Number of tags from each release group that were detected after release in 2014, including predator-type detections and detections omitted from the survival analysis.**

| Parameter | Release Group | | | Total |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| Number Released | 643 | 646 | 629 | 1,918 |
| Number Detected | 380 | 296 | 361 | 1,037 |
| Number Detected Downstream | 380 | 295 | 335 | 1,010 |
| Number Detected Upstream of Study Area | 165 | 183 | 357 | 705 |
| Number Detected in Study Area | 285 | 171 | 41 | 497 |
| Number Detected in San Joaquin River Route | 183 | 78 | 32 | 293 |
| Number Detected in Old River Route | 17 | 7 | 2 | 26 |
| Number Assigned to San Joaquin River Route | 166 | 74 | 30 | 270 |
| Number Assigned to Old River Route | 17 | 7 | 2 | 26 |

**Table 12. Number of tags observed from each release group at each detection site in 2014, including predator-type detections. Routes (SJR = San Joaquin River, OR = Old River) represent route assignment at the head of Old River. Pooled counts are summed over all receivers in array and all routes. Route could not be identified for some tags.**

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Release site at Durham Ferry | | | 643 | 646 | 629 | 1,918 |
| Durham Ferry Upstream | DFU | A0 | 0 | 4 | 44 | 48 |
| Durham Ferry Downstream | DFD | A2 | 77 | 135 | 287 | 499 |
| Banta Carbona (Pooled) | BCA | A3 | 108 | 59 | 88 | 255 |
| Mossdale (Pooled) | MOS | A4 | 284 | 171 | 41 | 496 |
| Head of Old River (Pooled) | HOR | B0 | 252 | 119 | 36 | 407 |
| Lathrop, Upstream | SJLU | A5a | 173 | 69 | 31 | 273 |
| Lathrop, Downstream | SJLD | A5b | 176 | 72 | 32 | 280 |
| Lathrop (Pooled) | SJL | A5 | 180 | 75 | 32 | 287 |
| Predator Removal Study 4 | RS4 | N1 | 139 | 57 | 27 | 223 |
| Predator Removal Study 5 | RS5 | N2 | 121 | 41 | 21 | 183 |
| Predator Removal Study 6 | RS6 | N3 | 97 | 34 | 15 | 146 |
| Predator Removal Study 7 | RS7 | N4 | 76 | 28 | 12 | 116 |
| Predator Removal Study 8 | RS8 | N5 | 58 | 21 | 8 | 87 |
| Predator Removal Study 9 | RS9 | N6 | 49 | 19 | 5 | 73 |
| Predator Removal Study 10 | RS10 | N7 | 46 | 17 | 5 | 68 |
| Garwood Bridge, Upstream | SJGU | A6a | 42 | 15 | 5 | 62 |
| Garwood Bridge, Downstream | SJGD | A6b | 42 | 15 | 5 | 62 |
| Garwood Bridge (Pooled) | SJG | A6 | 42 | 15 | 5 | 62 |
| Navy Drive Bridge, Upstream | SJNBU | A7a | 30 | 10 | 4 | 44 |
| Navy Drive Bridge, Downstream | SJNBD | A7b | 30 | 10 | 4 | 44 |
| Navy Drive Bridge (Pooled) | SJNB | A7 | 30 | 10 | 4 | 44 |
| Rough and Ready Island, Upstream | RRIU | R1a | 3 | 3 | 0 | 6 |
| Rough and Ready Island, Downstream | RRID | R1b | 3 | 3 | 0 | 6 |
| Rough and Ready Island (Pooled) | RRI | R1 | 3 | 3 | 0 | 6 |
| MacDonald Island Upstream | MACU | A8a | 2 | 1 | 0 | 3 |
| MacDonald Island Downstream | MACD | A8b | 2 | 1 | 0 | 3 |
| MacDonald Island (Pooled) | MAC | A8 | 2 | 1 | 0 | 3 |
| Medford Island East | MFE | A9a | 1 | 0 | 0 | 1 |
| Medford Island West | MFW | A9b | 1 | 0 | 0 | 1 |
| Medford Island (Pooled) | MFE/MFW | A9 | 1 | 0 | 0 | 1 |
| Turner Cut, Upstream | TCE | F1a | 0 | 2 | 0 | 2 |
| Turner Cut, Downstream | TCW | F1b | 0 | 2 | 0 | 2 |
| Turner Cut (Pooled) | TCE/TCW | F1 | 0 | 2 | 0 | 2 |
| Old River East, Upstream | OREU | B1a | 17 | 7 | 2 | 26 |
| Old River East, Downstream | ORED | B1b | 17 | 7 | 2 | 26 |
| Old River East (Pooled) | ORE | B1 | 17 | 7 | 2 | 26 |
| Old River South, Upstream | ORSU | B2a | 9 | 4 | 2 | 15 |
| Old River South, Downstream | ORSD | B2b | 9 | 4 | 2 | 15 |

**Table 12. (Continued)**

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Old River South (Pooled) | ORS | B2 | 9 | 4 | 2 | 15 |
| West Canal, Upstream | WCIU | B3a | 2 | 0 | 0 | 2 |
| West Canal, Downstream | WCID | B3b | 2 | 0 | 0 | 2 |
| West Canal (Pooled) | WCI | B3 | 2 | 0 | 0 | 2 |
| Old River at Highway 4, Upstream | OR4U | B4a | 0 | 0 | 0 | 0 |
| Old River at Highway 4, Downstream | OR4D | B4b | 0 | 0 | 0 | 0 |
| Old River at Highway 4 (Pooled) | OR4 | B4 | 0 | 0 | 0 | 0 |
| Old River at the San Joaquin | OSJ | B5 | 1 | 0 | 0 | 1 |
| Middle River Head, Upstream | MRHU | C1a | 0 | 0 | 0 | 0 |
| Middle River Head, Downstream | MRHD | C1b | 0 | 0 | 0 | 0 |
| Middle River Head (Pooled) | MRH | C1 | 0 | 0 | 0 | 0 |
| Middle River at Highway 4, Upstream | MR4U | C2a | 0 | 0 | 0 | 0 |
| Middle River at Highway 4, Downstream | MR4D | C2b | 0 | 0 | 0 | 0 |
| Middle River at Highway 4 (Pooled) | MR4 | C2 | 0 | 0 | 0 | 0 |
| Middle River at Middle River | MID | C3 | 0 | 0 | 0 | 0 |
| Radial Gates Upstream #1 | RGU1 | D1a | 2 | 0 | 0 | 2 |
| Radial Gates Upstream #2 | RGU2 | D1b | 2 | 0 | 0 | 2 |
| Radial Gates Upstream (Pooled) | RGU | D1 | 2 | 0 | 0 | 2 |
| Radial Gates Downstream #1 | RGD1 | D2a | 1 | 0 | 0 | 1 |
| Radial Gates Downstream #2 | RGD2 | D2b | 1 | 0 | 0 | 1 |
| Radial Gates Downstream (Pooled) | RGD | D2 | 1 | 0 | 0 | 1 |
| Central Valley Project Trashrack, Upstream | CVPU | E1a | 2 | 1 | 1 | 4 |
| Central Valley Project Trashrack, Downstream | CVPD | E1b | 1 | 1 | 1 | 3 |
| Central Valley Project Trashrack (Pooled) | CVP | E1 | 2 | 1 | 1 | 4 |
| Central Valley Project Holding Tank | CVPtank | E2 | 1 | 1 | 0 | 2 |
| Threemile Slough, Upstream | TMS | T1a | 0 | 0 | 0 | 0 |
| Threemile Slough, Downstream | TMN | T1b | 0 | 0 | 0 | 0 |
| Threemile Slough (Pooled) | TMS/TMN | T1 | 0 | 0 | 0 | 0 |
| Jersey Point East | JPE | G1a | 1 | 0 | 0 | 1 |
| Jersey Point West | JPW | G1b | 1 | 0 | 0 | 1 |
| Jersey Point: SJR Route | JPE/JPW | G1 | 1 | 0 | 0 | 1 |
| Jersey Point: OR Route | JPE/JPW | G1 | 0 | 0 | 0 | 0 |
| Jersey Point (Pooled) | JPE/JPW | G1 | 1 | 0 | 0 | 1 |
| False River West | FRW | H1a | 0 | 0 | 0 | 0 |
| False River East | FRE | H1b | 0 | 0 | 0 | 0 |
| False River: SJR Route | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| False River: OR Route | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| False River (Pooled) | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| Montezuma Slough, Upstream | MTZU | T2a | 0 | 0 | 0 | 0 |
| Montezuma Slough, Downstream | MTZD | T2b | 0 | 0 | 0 | 0 |

**Table 12. (Continued)**

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Montezuma Slough (Pooled) | MTZ | T2 | 0 | 0 | 0 | 0 |
| Spoonbill Slough, Upstream | SBSU | T3a | 0 | 0 | 0 | 0 |
| Spoonbill Slough, Downstream | SBSD | T3b | 0 | 0 | 0 | 0 |
| Spoonbill Slough (Pooled) | SBS | T3 | 0 | 0 | 0 | 0 |
| Chipps Island East | MAE | G2a | 1 | 0 | 0 | 1 |
| Chipps Island West | MAW | G2b | 1 | 0 | 0 | 1 |
| Chipps Island: SJR Route | MAE/MAW | G2 | 0 | 0 | 0 | 0 |
| Chipps Island: OR Route | MAE/MAW | G2 | 1 | 0 | 0 | 1 |
| Chipps Island (Pooled) | MAE/MAW | G2 | 1 | 0 | 0 | 1 |
| Benicia Bridge: SJR Route | BBR | G3 | 0 | 0 | 0 | 0 |
| Benicia Bridge: OR Route | BBR | G3 | 1 | 1 | 0 | 2 |
| Benicia Bridge | BBR | G3 | 1 | 1 | 0 | 2 |

Table 13. Number of tags observed from each release group at each detection site in 2014 and used in the survival analysis, including predator-type detections. Pooled counts are summed over all receivers in array. Route could not be identified for some tags.

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Release site at Durham Ferry | | | 643 | 646 | 629 | 1,918 |
| Durham Ferry Upstream | DFU | A0 | 0 | 2 | 39 | 41 |
| Durham Ferry Downstream | DFD | A2 | 77 | 134 | 273 | 484 |
| Banta Carbona (Pooled) | BCA | A3 | 108 | 56 | 87 | 251 |
| Mossdale (Pooled) | MOS | A4 | 284 | 168 | 41 | 493 |
| Lathrop, Upstream | SJLU | A5a | 159 | 66 | 28 | 253 |
| Lathrop, Downstream | SJLD | A5b | 163 | 67 | 30 | 260 |
| Lathrop | SJL | A5 | 166 | 73 | 30 | 269 |
| Garwood Bridge, Upstream | SJGU | A6a | 42 | 15 | 5 | 62 |
| Garwood Bridge, Downstream | SJGD | A6b | 42 | 15 | 5 | 62 |
| Garwood Bridge (Pooled) | SJG | A6 | 42 | 15 | 5 | 62 |
| Navy Drive Bridge, Upstream | SJNBU | A7a | 29 | 9 | 3 | 41 |
| Navy Drive Bridge, Downstream | SJNBD | A7b | 29 | 9 | 3 | 41 |
| Navy Drive Bridge (Pooled) | SJNB | A7 | 29 | 9 | 3 | 41 |
| Rough and Ready Island, Upstream | RRIU | R1a | 3 | 3 | 0 | 6 |
| Rough and Ready Island, Downstream | RRID | R1b | 2 | 3 | 0 | 5 |
| Rough and Ready Island (Pooled) | RRI | R1 | 3 | 3 | 0 | 6 |
| MacDonald Island Upstream | MACU | A8a | 2 | 0 | 0 | 2 |
| MacDonald Island Downstream | MACD | A8b | 2 | 1 | 0 | 3 |
| MacDonald Island (Pooled) | MAC | A8 | 2 | 1 | 0 | 3 |
| Medford Island East | MFE | A9a | 1 | 0 | 0 | 1 |
| Medford Island West | MFW | A9b | 1 | 0 | 0 | 1 |
| Medford Island (Pooled) | MFE/MFW | A9 | 1 | 0 | 0 | 1 |
| Turner Cut, Upstream | TCE | F1a | 0 | 2 | 0 | 2 |
| Turner Cut, Downstream | TCW | F1b | 0 | 2 | 0 | 2 |
| Turner Cut (Pooled) | TCE/TCW | F1 | 0 | 2 | 0 | 2 |
| Old River East, Upstream | OREU | B1a | 17 | 7 | 2 | 26 |
| Old River East, Downstream | ORED | B1b | 17 | 7 | 2 | 26 |
| Old River East (Pooled) | ORE | B1 | 17 | 7 | 2 | 26 |
| Old River South Upstream | ORSU | B2a | 9 | 4 | 2 | 15 |
| Old River South Downstream | ORSD | B2b | 9 | 4 | 2 | 15 |
| Old River South (Pooled) | ORS | B2 | 9 | 4 | 2 | 15 |
| Old River at Highway 4 (Pooled) | OR4 | B4 | 0 | 0 | 0 | 0 |
| Middle River Head (Pooled) | MRH | C1 | 0 | 0 | 0 | 0 |
| Middle River at Highway 4 (Pooled) | MR4 | C2 | 0 | 0 | 0 | 0 |
| Radial Gates Upstream (Pooled) | RGU | D1 | 1 | 0 | 0 | 1 |
| Radial Gates Downstream #1 | RGD1 | D2a | 1 | 0 | 0 | 1 |
| Radial Gates Downstream #2 | RGD2 | D2b | 1 | 0 | 0 | 1 |
| Radial Gates Downstream (Pooled) | RGD | D2 | 1 | 0 | 0 | 1 |

**Table 13. (Continued)**

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Central Valley Project Trashrack (Pooled) | CVP | E1 | 2 | 1 | 1 | 4 |
| Central Valley Project Holding Tank | CVPtank | E2 | 1 | 1 | 0 | 2 |
| Chipps Island East | MAE | G2a | 1 | 0 | 0 | 1 |
| Chipps Island West | MAW | G2b | 1 | 0 | 0 | 1 |
| Chipps Island: SJR Route | MAE/MAW | G2 | 0 | 0 | 0 | 0 |
| Chipps Island: OR Route | MAE/MAW | G2 | 1 | 0 | 0 | 1 |
| Chipps Island (Pooled) | MAE/MAW | G2 | 1 | 0 | 0 | 1 |
| Benicia Bridge: SJR Route | BBR | G3 | 0 | 0 | 0 | 0 |
| Benicia Bridge: OR Route | BBR | G3 | 1 | 1 | 0 | 2 |
| Benicia Bridge | BBR | G3 | 1 | 1 | 0 | 2 |

**Table 14. Number of tags from each release group in 2014 first classified as in a predator at each detection site, based on the predator filter.**

| Detection Site | Site Code | Survival Model Code | Release Groups: Classified as Predator on Arrival at Site: 1 | 2 | 3 | Total | Classified as Predator on Departure from Site: 1 | 2 | 3 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Durham Ferry Upstream | DFU | A0 | 0 | 3 | 24 | 27 | 0 | 0 | 7 | 7 |
| Durham Ferry Downstream | DFD | A2 | 12 | 11 | 11 | 34 | 2 | 7 | 28 | 37 |
| Banta Carbona | BCA | A3 | 1 | 5 | 3 | 9 | 4 | 1 | 10 | 15 |
| Mossdale | MOS | A4 | 12 | 2 | 0 | 14 | 4 | 3 | 0 | 7 |
| Head of Old River | HOR | B0 | 3 | 4 | 1 | 8 | 15 | 4 | 3 | 22 |
| Lathrop | SJL | A5 | 1 | 1 | 1 | 3 | 8 | 4 | 3 | 15 |
| Predator Removal Study 4 | RS4 | N1 | 2 | 2 | 1 | 5 | 7 | 5 | 3 | 15 |
| Predator Removal Study 5 | RS5 | N2 | 2 | 0 | 0 | 2 | 3 | 0 | 2 | 5 |
| Predator Removal Study 6 | RS6 | N3 | 1 | 0 | 0 | 1 | 8 | 1 | 1 | 10 |
| Predator Removal Study 7 | RS7 | N4 | 0 | 1 | 1 | 2 | 8 | 2 | 1 | 11 |
| Predator Removal Study 8 | RS8 | N5 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 4 |
| Predator Removal Study 9 | RS9 | N6 | 1 | 0 | 0 | 1 | 2 | 1 | 1 | 4 |
| Predator Removal Study 10 | RS10 | N7 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Garwood Bridge | SJG | A6 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 3 |
| Navy Drive Bridge | SJNB | A7 | 1 | 0 | 0 | 1 | 3 | 0 | 0 | 3 |
| Rough and Ready Island | RRI | R1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MacDonald Island | MAC | A8 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Medford Island | MFE/MFW | A9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Old River East | ORE | B1 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 4 |
| Old River South | ORS | B2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| West Canal | WCL | B3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Old River at Highway 4 | OR4 | B4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Old River at the San Joaquin | OSJ | B5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Middle River Head | MRH | C1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Middle River at Highway 4 | MR4 | C2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Middle River near Empire Cut | MRE | C3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Radial Gates Upstream | RGU | D1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Radial Gates Downstream | RGD | D2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Central Valley Project Trashrack | CVP | E1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Central Valley Project Holding Tank | CVPtank | E2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Turner Cut | TCE/TCW | F1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jersey Point | JPE/JPW | G1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chipps Island | MAE/MAW | G2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Benicia Bridge | BBR | G3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| False River | FRE/FRW | H1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Threemile Slough | TMS/TMN | T1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Montezuma Slough | MTZ | T2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spoonbill Slough | SBS | T3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Tags | | | 36 | 30 | 42 | 108 | 76 | 31 | 60 | 167 |

**Table 15. Number of tags from each release group that were detected after release in 2014, excluding predator-type detections and detections omitted from the survival analysis.**

| Parameter | Release Group | | | Total |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| Number Released | 643 | 646 | 629 | 1,918 |
| Number Detected | 368 | 287 | 341 | 996 |
| Number Detected Downstream | 368 | 287 | 327 | 982 |
| Number Detected Upstream of Study Area | 153 | 173 | 337 | 663 |
| Number Detected in Study Area | 285 | 171 | 41 | 497 |
| Number Detected in San Joaquin River Route | 180 | 78 | 32 | 290 |
| Number Detected in Old River Route | 17 | 7 | 2 | 26 |
| Number Assigned to San Joaquin River Route | 167 | 73 | 30 | 270 |
| Number Assigned to Old River Route | 17 | 7 | 2 | 26 |

**Table 16. Number of tags observed from each release group at each detection site in 2014, excluding predator-type detections. Routes (SJR = San Joaquin River, OR = Old River) represent route assignment at the head of Old River. Pooled counts are summed over all receivers in array and all routes. Route could not be identified for some tags.**

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Release site at Durham Ferry | | | 643 | 646 | 629 | 1,918 |
| Durham Ferry Upstream | DFU | A0 | 0 | 0 | 22 | 22 |
| Durham Ferry Downstream | DFD | A2 | 65 | 128 | 278 | 471 |
| Banta Carbona (Pooled) | BCA | A3 | 108 | 55 | 87 | 250 |
| Mossdale (Pooled) | MOS | A4 | 284 | 171 | 41 | 496 |
| Head of Old River (Pooled) | HOR | B0 | 252 | 119 | 36 | 407 |
| Lathrop, Upstream | SJLU | A5a | 170 | 69 | 31 | 270 |
| Lathrop, Downstream | SJLD | A5b | 174 | 72 | 32 | 278 |
| Lathrop (Pooled) | SJL | A5 | 177 | 75 | 32 | 284 |
| Predator Removal Study 4 | RS4 | N1 | 137 | 56 | 26 | 219 |
| Predator Removal Study 5 | RS5 | N2 | 117 | 40 | 20 | 177 |
| Predator Removal Study 6 | RS6 | N3 | 95 | 32 | 14 | 141 |
| Predator Removal Study 7 | RS7 | N4 | 74 | 26 | 12 | 112 |
| Predator Removal Study 8 | RS8 | N5 | 56 | 20 | 8 | 84 |
| Predator Removal Study 9 | RS9 | N6 | 47 | 18 | 4 | 69 |
| Predator Removal Study 10 | RS10 | N7 | 44 | 17 | 4 | 65 |
| Garwood Bridge, Upstream | SJGU | A6a | 41 | 15 | 3 | 59 |
| Garwood Bridge, Downstream | SJGD | A6b | 41 | 15 | 3 | 59 |
| Garwood Bridge (Pooled) | SJG | A6 | 41 | 15 | 3 | 59 |
| Navy Drive Bridge, Upstream | SJNBU | A7a | 28 | 10 | 2 | 40 |
| Navy Drive Bridge, Downstream | SJNBD | A7b | 28 | 10 | 2 | 40 |
| Navy Drive Bridge (Pooled) | SJNB | A7 | 28 | 10 | 2 | 40 |
| Rough and Ready Island, Upstream | RRIU | R1a | 3 | 3 | 0 | 6 |
| Rough and Ready Island, Downstream | RRID | R1b | 3 | 3 | 0 | 6 |
| Rough and Ready Island (Pooled) | RRI | R1 | 3 | 3 | 0 | 6 |
| MacDonald Island Upstream | MACU | A8a | 2 | 1 | 0 | 3 |
| MacDonald Island Downstream | MACD | A8b | 2 | 1 | 0 | 3 |
| MacDonald Island (Pooled) | MAC | A8 | 2 | 1 | 0 | 3 |
| Medford Island East | MFE | A9a | 1 | 0 | 0 | 1 |
| Medford Island West | MFW | A9b | 1 | 0 | 0 | 1 |
| Medford Island (Pooled) | MFE/MFW | A9 | 1 | 0 | 0 | 1 |
| Turner Cut, Upstream | TCE | F1a | 0 | 2 | 0 | 2 |
| Turner Cut, Downstream | TCW | F1b | 0 | 2 | 0 | 2 |
| Turner Cut (Pooled) | TCE/TCW | F1 | 0 | 2 | 0 | 2 |
| Old River East, Upstream | OREU | B1a | 17 | 7 | 2 | 26 |
| Old River East, Downstream | ORED | B1b | 17 | 7 | 2 | 26 |
| Old River East (Pooled) | ORE | B1 | 17 | 7 | 2 | 26 |
| Old River South, Upstream | ORSU | B2a | 9 | 4 | 2 | 15 |
| Old River South, Downstream | ORSD | B2b | 9 | 4 | 2 | 15 |

Table 16. (Continued)

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Old River South (Pooled) | ORS | B2 | 9 | 4 | 2 | 15 |
| West Canal, Upstream | WCIU | B3a | 2 | 0 | 0 | 2 |
| West Canal, Downstream | WCID | B3b | 2 | 0 | 0 | 2 |
| West Canal (Pooled) | WCI | B3 | 2 | 0 | 0 | 2 |
| Old River at Highway 4, Upstream | OR4U | B4a | 0 | 0 | 0 | 0 |
| Old River at Highway 4, Downstream | OR4D | B4b | 0 | 0 | 0 | 0 |
| Old River at Highway 4 (Pooled) | OR4 | B4 | 0 | 0 | 0 | 0 |
| Old River at the San Joaquin | OSJ | B5 | 1 | 0 | 0 | 1 |
| Middle River Head, Upstream | MRHU | C1a | 0 | 0 | 0 | 0 |
| Middle River Head, Downstream | MRHD | C1b | 0 | 0 | 0 | 0 |
| Middle River Head (Pooled) | MRH | C1 | 0 | 0 | 0 | 0 |
| Middle River at Highway 4, Upstream | MR4U | C2a | 0 | 0 | 0 | 0 |
| Middle River at Highway 4, Downstream | MR4D | C2b | 0 | 0 | 0 | 0 |
| Middle River at Highway 4 (Pooled) | MR4 | C2 | 0 | 0 | 0 | 0 |
| Middle River at Middle River | MID | C3 | 0 | 0 | 0 | 0 |
| Radial Gates Upstream #1 | RGU1 | D1a | 2 | 0 | 0 | 2 |
| Radial Gates Upstream #2 | RGU2 | D1b | 2 | 0 | 0 | 2 |
| Radial Gates Upstream (Pooled) | RGU | D1 | 2 | 0 | 0 | 2 |
| Radial Gates Downstream #1 | RGD1 | D2a | 1 | 0 | 0 | 1 |
| Radial Gates Downstream #2 | RGD2 | D2b | 1 | 0 | 0 | 1 |
| Radial Gates Downstream (Pooled) | RGD | D2 | 1 | 0 | 0 | 1 |
| Central Valley Project Trashrack, Upstream | CVPU | E1a | 2 | 1 | 1 | 4 |
| Central Valley Project Trashrack, Downstream | CVPD | E1b | 1 | 1 | 1 | 3 |
| Central Valley Project Trashrack (Pooled) | CVP | E1 | 2 | 1 | 1 | 4 |
| Central Valley Project Holding Tank | CVPtank | E2 | 1 | 1 | 0 | 2 |
| Threemile Slough, Upstream | TMS | T1a | 0 | 0 | 0 | 0 |
| Threemile Slough, Downstream | TMN | T1b | 0 | 0 | 0 | 0 |
| Threemile Slough (Pooled) | TMS/TMN | T1 | 0 | 0 | 0 | 0 |
| Jersey Point East | JPE | G1a | 1 | 0 | 0 | 1 |
| Jersey Point West | JPW | G1b | 1 | 0 | 0 | 1 |
| Jersey Point: SJR Route | JPE/JPW | G1 | 1 | 0 | 0 | 1 |
| Jersey Point: OR Route | JPE/JPW | G1 | 0 | 0 | 0 | 0 |
| Jersey Point (Pooled) | JPE/JPW | G1 | 1 | 0 | 0 | 1 |
| False River West | FRW | H1a | 0 | 0 | 0 | 0 |
| False River East | FRE | H1b | 0 | 0 | 0 | 0 |
| False River: SJR Route | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| False River: OR Route | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| False River (Pooled) | FRE/FRW | H1 | 0 | 0 | 0 | 0 |
| Montezuma Slough, Upstream | MTZU | T2a | 0 | 0 | 0 | 0 |
| Montezuma Slough, Downstream | MTZD | T2b | 0 | 0 | 0 | 0 |

Table 16. (Continued)

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Montezuma Slough (Pooled) | MTZ | T2 | 0 | 0 | 0 | 0 |
| Spoonbill Slough, Upstream | SBSU | T3a | 0 | 0 | 0 | 0 |
| Spoonbill Slough, Downstream | SBSD | T3b | 0 | 0 | 0 | 0 |
| Spoonbill Slough (Pooled) | SBS | T3 | 0 | 0 | 0 | 0 |
| Chipps Island East | MAE | G2a | 1 | 0 | 0 | 1 |
| Chipps Island West | MAW | G2b | 1 | 0 | 0 | 1 |
| Chipps Island: SJR Route | MAE/MAW | G2 | 0 | 0 | 0 | 0 |
| Chipps Island: OR Route | MAE/MAW | G2 | 1 | 0 | 0 | 1 |
| Chipps Island (Pooled) | MAE/MAW | G2 | 1 | 0 | 0 | 1 |
| Benicia Bridge: SJR Route | BBR | G3 | 0 | 0 | 0 | 0 |
| Benicia Bridge: OR Route | BBR | G3 | 0 | 1 | 0 | 1 |
| Benicia Bridge | BBR | G3 | 0 | 1 | 0 | 1 |

**Table 17. Number of tags observed from each release group at each detection site in 2014 and used in the survival analysis, excluding predator-type detections. Pooled counts are summed over all receivers in array. Route could not be identified for some tags.**

| Detection Site | Site Code | Survival Model Code | Release Group 1 | Release Group 2 | Release Group 3 | Total |
|---|---|---|---|---|---|---|
| Release site at Durham Ferry | | | 643 | 646 | 629 | 1,918 |
| Durham Ferry Upstream | DFU | A0 | 0 | 0 | 20 | 20 |
| Durham Ferry Downstream | DFD | A2 | 65 | 128 | 271 | 464 |
| Banta Carbona (Pooled) | BCA | A3 | 108 | 55 | 87 | 250 |
| Mossdale (Pooled) | MOS | A4 | 284 | 170 | 41 | 495 |
| Lathrop, Upstream | SJLU | A5a | 160 | 66 | 29 | 255 |
| Lathrop, Downstream | SJLD | A5b | 165 | 69 | 30 | 264 |
| Lathrop | SJL | A5 | 167 | 72 | 30 | 269 |
| Garwood Bridge, Upstream | SJGU | A6a | 41 | 15 | 3 | 59 |
| Garwood Bridge, Downstream | SJGD | A6b | 41 | 15 | 3 | 59 |
| Garwood Bridge (Pooled) | SJG | A6 | 41 | 15 | 3 | 59 |
| Navy Drive Bridge, Upstream | SJNBU | A7a | 28 | 9 | 1 | 38 |
| Navy Drive Bridge, Downstream | SJNBD | A7b | 28 | 9 | 1 | 38 |
| Navy Drive Bridge (Pooled) | SJNB | A7 | 28 | 9 | 1 | 38 |
| Rough and Ready Island, Upstream | RRIU | R1a | 2 | 3 | 0 | 5 |
| Rough and Ready Island, Downstream | RRID | R1b | 2 | 3 | 0 | 5 |
| Rough and Ready Island (Pooled) | RRI | R1 | 2 | 3 | 0 | 5 |
| MacDonald Island Upstream | MACU | A8a | 2 | 1 | 0 | 3 |
| MacDonald Island Downstream | MACD | A8b | 2 | 1 | 0 | 3 |
| MacDonald Island (Pooled) | MAC | A8 | 2 | 1 | 0 | 3 |
| Medford Island East | MFE | A9a | 1 | 0 | 0 | 1 |
| Medford Island West | MFW | A9b | 1 | 0 | 0 | 1 |
| Medford Island (Pooled) | MFE/MFW | A9 | 1 | 0 | 0 | 1 |
| Turner Cut, Upstream | TCE | F1a | 0 | 2 | 0 | 2 |
| Turner Cut, Downstream | TCW | F1b | 0 | 2 | 0 | 2 |
| Turner Cut (Pooled) | TCE/TCW | F1 | 0 | 2 | 0 | 2 |
| Old River East, Upstream | OREU | B1a | 17 | 7 | 2 | 26 |
| Old River East, Downstream | ORED | B1b | 17 | 7 | 2 | 26 |
| Old River East (Pooled) | ORE | B1 | 17 | 7 | 2 | 26 |
| Old River South Upstream | ORSU | B2a | 9 | 4 | 2 | 15 |
| Old River South Downstream | ORSD | B2b | 9 | 4 | 2 | 15 |
| Old River South (Pooled) | ORS | B2 | 9 | 4 | 2 | 15 |
| Old River at Highway 4 (Pooled) | OR4 | B4 | 0 | 0 | 0 | 0 |
| Middle River Head (Pooled) | MRH | C1 | 0 | 0 | 0 | 0 |
| Middle River at Highway 4 (Pooled) | MR4 | C2 | 0 | 0 | 0 | 0 |
| Radial Gates Upstream (Pooled) | RGU | D1 | 1 | 0 | 0 | 1 |
| Radial Gates Downstream #1 | RGD1 | D2a | 1 | 0 | 0 | 1 |
| Radial Gates Downstream #2 | RGD2 | D2b | 1 | 0 | 0 | 1 |
| Radial Gates Downstream (Pooled) | RGD | D2 | 1 | 0 | 0 | 1 |

**Table 17. (Continued)**

| Detection Site | Site Code | Survival Model Code | Release Group | | | Total |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | |
| Central Valley Project Trashrack (Pooled) | CVP | E1 | 2 | 1 | 1 | 4 |
| Central Valley Project Holding Tank | CVPtank | E2 | 1 | 1 | 0 | 2 |
| Chipps Island East | MAE | G2a | 1 | 0 | 0 | 1 |
| Chipps Island West | MAW | G2b | 1 | 0 | 0 | 1 |
| Chipps Island: SJR Route | MAE/MAW | G2 | 0 | 0 | 0 | 0 |
| Chipps Island: OR Route | MAE/MAW | G2 | 1 | 0 | 0 | 1 |
| Chipps Island (Pooled) | MAE/MAW | G2 | 1 | 0 | 0 | 1 |
| Benicia Bridge: SJR Route | BBR | G3 | 0 | 0 | 0 | 0 |
| Benicia Bridge: OR Route | BBR | G3 | 0 | 1 | 0 | 1 |
| Benicia Bridge | BBR | G3 | 0 | 1 | 0 | 1 |

**Table 18. Number of juvenile Chinook Salmon tagged by each surgeon in each release group during the 2014 tagging study.**

| Surgeon | Release Group | | | Total Tags |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| A | 216 | 215 | 210 | 641 |
| B | 212 | 216 | 209 | 637 |
| C | 215 | 215 | 210 | 640 |
| Total | 643 | 646 | 629 | 1,918 |

**Table 19. Release size and counts of tag detections at key detection sites by surgeon in 2014, excluding predator-type detections. Asterisk indicates the site was used in chi-square test of independence. Letter "a" indicates the site was pooled with other sites for chi-square test of independence.**

| Detection Site | Surgeon | | |
|---|---|---|---|
| | A | B | C |
| Release at Durham Ferry* | 641 | 637 | 640 |
| Banta Carbona (BCA)* | 91 | 73 | 86 |
| Mossdale (MOS)* | 176 | 155 | 164 |
| Lathrop (SJL)* | 95 | 82 | 92 |
| Garwood Bridge (SJG)* | 21 | 19 | 19 |
| Navy Bridge (SJNB)* | 13 | 12 | 13 |
| MacDonald Island (MAC) | 1 | 2 | 0 |
| Old River East (ORE)* | 15 | 5 | 6 |
| Old River South (ORS)*[a] | 8 | 3 | 4 |
| Clifton Court Forebay Exterior (RGU)*[a] | 0 | 1 | 0 |
| Clifton Court Forebay Interior (RGD) | 0 | 1 | 0 |
| Central Valley Project Trash Rack (CVP)*[a] | 3 | 1 | 0 |
| Central Valley Project Holding Tank (CVPtank) | 1 | 1 | 0 |
| Chipps Island (MAE/MAW) | 0 | 1 | 0 |
| Benicia Bridge (BBR) | 1 | 0 | 0 |

**Table 20. Performance metric estimates (standard error in parentheses) for tagged juvenile Chinook Salmon released in the 2014 tagging study, excluding predator-type detections. Southern Delta (SD) survival extended to MacDonald Island and Turner Cut in Route A. Population-level estimates were from pooled release groups 2 and 3.**

| | Release Group | | | |
|---|---|---|---|---|
| Parameter | 1[a] | 2 | 3 | Population Estimate (Releases 2 and 3) |
| $\psi_{AA}$ | 0.54 (0.20) | 0.55 (0.20) | 0.56 (0.21) | 0.55 (0.20) |
| $\psi_{AF}$ | 0.36 (0.20) | 0.36 (0.20) | 0.38 (0.21) | 0.37 (0.20) |
| $\psi_{A}$[b] | 0.91 (0.02) | 0.91 (0.03) | 0.94 (0.04) | 0.92 (0.02) |
| $\psi_{B}$[b] | 0.09 (0.02) | 0.09 (0.03) | 0.06 (0.04) | 0.08 (0.02) |
| $S_{A}$[d] | 0[c] | NA | NA | NA |
| $S_{B}$[d] | 0.04[c] (0.04) | NA | NA | NA |
| $S_{Total}$[d] | 0.004 (0.003) | NA | NA | NA |
| $S_{A(SD)}$[e] | 0.01 (0.01) | 0.01 (<0.01) | 0.003 (0.004) | 0.01 (<0.01) |
| $S_{B(SD)}$[e] | 0.12 (0.05) | 0.09 (0.04) | 0.26 (0.10) | 0.12 (0.05) |
| $S_{Total(SD)}$[e] | 0.02 (0.01) | 0.01 (0.01) | 0.02 (0.01) | 0.02 (0.01) |
| $\phi_{A1A4}$ | 0.44 (0.02) | 0.26 (0.02) | 0.06 (0.01) | 0.16 (0.01) |

a = Parameter estimates for group 1 represent joint fish-tag survival

b = Significant preference for route A (San Joaquin River Route) ($\alpha$ = 0.05) for all release groups and for population estimate

c = No significant difference between route A and route B estimates (P = 0.1516) (tested only for Delta survival)

d = Too few tags were detected at Chipps Island to adequately estimate detection probability

e = Parameters were equated across all three release groups in the final reaches of the SD model; affects estimates of $\psi_{AA}$, $\psi_{AF}$, $S_{A(SD)}$, $S_{B(SD)}$, $S_{Total(SD)}$

**Table 21. Performance metric estimates (standard error in parentheses) for tagged juvenile Chinook Salmon released in the 2014 tagging study, including predator-type detections. Southern Delta (SD) survival extended to MacDonald Island and Turner Cut in Route A. Population-level estimates were from pooled release groups 2 and 3.**

| Parameter | Release Group | | | Population Estimate (Releases 2 and 3) |
|---|---|---|---|---|
| | 1[a] | 2 | 3 | |
| $\psi_{AA}$ | 0.55 (0.20) | 0.55 (0.20) | 0.57 (0.21) | 0.56 (0.21) |
| $\psi_{AF}$ | 0.36 (0.20) | 0.36 (0.20) | 0.37 (0.20) | 0.36 (0.20) |
| $\psi_A$[b] | 0.91 (0.02) | 0.91 (0.03) | 0.93 (0.04) | 0.92 (0.02) |
| $\psi_B$[b] | 0.09 (0.02) | 0.08 (0.03) | 0.06 (0.04) | 0.08 (0.02) |
| $S_A$[d] | 0[c] | NA | NA | NA |
| $S_B$[d] | 0.04[c] (0.04) | NA | NA | NA |
| $S_{Total}$[d] | 0.004 (0.003) | NA | NA | NA |
| $S_{A(SD)}$[e] | 0.01 (0.01) | 0.01 (<0.01) | 0.01 (0.01) | 0.01 (<0.01) |
| $S_{B(SD)}$[e] | 0.11 (0.05) | 0.09 (0.05) | 0.26 (0.10) | 0.12 (0.05) |
| $S_{Total(SD)}$[e] | 0.02 (0.05) | 0.01 (0.01) | 0.02 (0.01) | 0.02 (0.01) |
| $\phi_{A1A4}$ | 0.44 (0.02) | 0.26 (0.02) | 0.06 (0.01) | 0.16 (0.01) |

a = Parameter estimates for group 1 represent joint fish-tag survival

b = significant preference for route A (San Joaquin River Route) ($\alpha$=0.05) for all release groups and for population estimate

c = no significant difference between route A and route B estimates (P = 0.1516) (tested only for Delta survival)

d = too few tags were detected at Chipps Island to adequately estimate detection probability

e = Parameters were equated across all three release groups in the final reaches of the SD model; affects estimates of $\psi_{AA}$, $\psi_{AF}$, $S_{A(SD)}$, $S_{B(SD)}$, $S_{Total(SD)}$

**Table 22. Estimates (standard errors in parentheses) of model survival and transition parameters by release group, and of the difference ($\Delta$) between release group estimates: $\Delta$ = Release group 2 - Release group 3. P = P-value from one-sized *Z*-test of $\Delta > 0$. Estimates were based on data that excluded predator-type detections. Asterisk indicates significant (positive) difference between release groups for family-wise $\alpha = 0.10$.**

| Parameter | Release 2 | Release 3 | $\Delta$ | P |
|---|---|---|---|---|
| $S_{A2}$ | 0.68 (0.13) | 0.20 (0.03) | 0.50 (0.13) | 0.0001* |
| $S_{A3}$ | 0.42 (0.07) | 0.37 (0.05) | 0.05 (0.08) | 0.2768 |
| $S_{A4}$ | 0.47 (0.04) | 0.78 (0.06) | -0.31 (0.08) | 1.0000[a] |
| $S_{A5}$ | 0.20 (0.05) | 0.10 (0.05) | 0.10 (0.07) | 0.0741 |
| $\phi_{A1,A2}$ | 0.93 (0.10) | 0.90 (0.09) | 0.03 (0.14) | 0.4071 |
| $\phi_{A1,A4}$ | 0.26 (0.02) | 0.06 (0.01) | 0.20 (0.02) | < 0.0001* |
| $\lambda_{A4}$ | 0.006 (0.006) | 0 (0) | 0.006 (0.006) | 0.1579 |
| $\phi_{E1,G2}$ | 0.13 (0.05) | 0 (0) | 0.13 (0.05) | 0.4257 |

a = significant negative difference between release groups for family-wise $\alpha = 0.10$

**Table 23a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon from release at Durham Ferry during the 2014 tagging study, excluding predator-type detections. Standard errors are in parentheses. There were too few detections at the MFE/MFW and JPE/JPW receivers to estimate travel time to those sites. There were no detections at the OR4, MRH, MR4, or FRE/FRW receivers. See Table 23b for travel time from release with predator-type detections.**

| Detection Site and Route | Without Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Release 1 | | Release 2 | | Release 3 | | Releases 2, 3 | |
| | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Durham Ferry Upstream (DFU) | 0 | NA | 0 | NA | 20 | 0.28 (0.05) | 20 | 0.28 (0.05) |
| Durham Ferry Downstream (DFD) | 65 | 0.04 (0.00) | 128 | 0.05 (0.00) | 271 | 0.06 (0.00) | 399 | 0.05 (0.00) |
| Banta Carbona (BCA) | 108 | 0.34 (0.02) | 55 | 0.37 (0.03) | 87 | 0.52 (0.03) | 142 | 0.45 (0.02) |
| Mossdale (MOS) | 284 | 0.75 (0.02) | 170 | 0.73 (0.02) | 41 | 1.17 (0.07) | 211 | 0.79 (0.02) |
| Lathrop (SJL) | 167 | 1.10 (0.03) | 72 | 1.12 (0.06) | 30 | 1.53 (0.13) | 102 | 1.22 (0.06) |
| Garwood Bridge (SJG) | 41 | 2.24 (0.13) | 15 | 2.58 (0.27) | 3 | 3.64 (0.37) | 18 | 2.71 (0.26) |
| Navy Drive Bridge (SJNB) | 28 | 2.35 (0.15) | 9 | 2.69 (0.39) | 1 | 3.82 (NA) | 10 | 2.77 (0.38) |
| Rough and Ready Island (RRI) | 2 | 4.22 (0.43) | 3 | 4.41 (1.06) | 0 | NA | 3 | 4.41 (1.06) |
| MacDonald Island (MAC) | 2 | 3.65 (1.49) | 1 | 1.87 (NA) | 0 | NA | 1 | 1.87 (NA) |
| Turner Cut | 0 | NA | 2 | 2.57 (0.28) | 0 | NA | 2 | 2.57 (0.28) |
| Old River East (ORE) | 17 | 1.29 (0.11) | 7 | 1.24 (0.19) | 2 | 1.33 (0.67) | 9 | 1.26 (0.18) |
| Old River South (ORS) | 9 | 1.78 (0.17) | 4 | 1.48 (0.29) | 2 | 1.66 (0.74) | 6 | 1.53 (0.26) |
| Radial Gates Upstream (DFU) | 1 | 3.29 (NA) | 0 | NA | 0 | NA | 0 | NA |
| Radial Gates Downstream (DFD) | 1 | 3.30 (NA) | 0 | NA | 0 | NA | 0 | NA |
| Central Valley Project Trashrack (CVP) | 2 | 4.20 (1.89) | 1 | 2.27 (NA) | 1 | 2.64 (NA) | 2 | 2.44 (0.18) |
| Central Valley Project Holding Tank (CVPtank) | 1 | 3.13 (NA) | 1 | 2.35 (NA) | 0 | NA | 1 | 2.35 (NA) |
| Chipps Island (MAE/MAW), SJR Route | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| Chipps Island (MAE/MAW), OR Route | 1 | 6.04 (NA) | 0 | NA | 0 | NA | 0 | NA |
| Chipps Island (MAE/MAW) | 1 | 6.04 (NA) | 0 | NA | 0 | NA | 0 | NA |
| Benicia Bridge (BBR), SJR Route | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| Benicia Bridge (BBR), OR Route | 0 | NA | 1 | 4.99 (NA) | 0 | NA | 1 | 4.99 (NA) |
| Benicia Bridge (BBR) | 0 | NA | 1 | 4.99 (NA) | 0 | NA | 1 | 4.99 (NA) |

**Table 23b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon from release at Durham Ferry during the 2014 tagging study, including predator-type detections. Standard errors are in parentheses. There were too few detections at the MFE/MFW and JPE/JPW receivers to estimate travel time to those sites. There were no detections at the OR4, MRH, MR4, or FRE/FRW receivers. See Table 23a for travel time from release without predator-type detections.**

| Detection Site and Route | With Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Release 1 | | Release 2 | | Release 3 | | Releases 2, 3 | |
| | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Durham Ferry Upstream (DFU) | 0 | NA | 2 | 6.57 (5.42) | 39 | 0.64 (0.15) | 41 | 0.67 (0.16) |
| Durham Ferry Downstream (DFD) | 77 | 0.05 (0.00) | 134 | 0.05 (0.00) | 273 | 0.06 (0.00) | 407 | 0.06 (0.00) |
| Banta Carbona (BCA) | 108 | 0.34 (0.02) | 56 | 0.39 (0.03) | 87 | 0.55 (0.04) | 143 | 0.47 (0.03) |
| Mossdale (MOS) | 284 | 0.78 (0.02) | 168 | 0.74 (0.02) | 41 | 1.19 (0.08) | 209 | 0.79 (0.03) |
| Lathrop (SJL) | 166 | 1.11 (0.04) | 73 | 1.18 (0.07) | 30 | 1.60 (0.15) | 103 | 1.28 (0.07) |
| Garwood Bridge (SJG) | 42 | 2.28 (0.14) | 15 | 2.58 (0.27) | 5 | 3.59 (0.36) | 20 | 2.77 (0.25) |
| Navy Drive Bridge (SJNB) | 29 | 2.44 (0.17) | 9 | 2.69 (0.39) | 3 | 3.66 (0.58) | 12 | 2.88 (0.36) |
| Rough and Ready Island (RRI) | 3 | 3.92 (0.35) | 3 | 4.41 (1.06) | 0 | NA | 3 | 4.41 (1.06) |
| MacDonald Island (MAC) | 2 | 3.65 (1.49) | 1 | 37.09 (NA) | 0 | NA | 1 | 37.09 (NA) |
| Turner Cut | 0 | NA | 2 | 2.57 (0.28) | 0 | NA | 2 | 2.57 (0.28) |
| Old River East (ORE) | 17 | 1.29 (0.11) | 7 | 1.24 (0.19) | 2 | 1.33 (0.67) | 9 | 1.26 (0.18) |
| Old River South (ORS) | 9 | 1.78 (0.17) | 4 | 1.48 (0.29) | 2 | 1.66 (0.74) | 6 | 1.53 (0.26) |
| Radial Gates Upstream (DFU) | 1 | 3.29 (NA) | 0 | NA | 0 | NA | 0 | NA |
| Radial Gates Downstream (DFD) | 1 | 3.30 (NA) | 0 | NA | 0 | NA | 0 | NA |
| Central Valley Project Trashrack (CVP) | 2 | 4.20 (1.89) | 1 | 2.27 (NA) | 1 | 2.64 (NA) | 2 | 2.44 (0.18) |
| Central Valley Project Holding Tank (CVPtank) | 1 | 3.13 (NA) | 1 | 2.35 (NA) | 0 | NA | 1 | 2.35 (NA) |
| Chipps Island (MAE/MAW), SJR Route | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| Chipps Island (MAE/MAW), OR Route | 1 | 7.68 (NA) | 0 | NA | 0 | NA | 0 | NA |
| Chipps Island (MAE/MAW) | 1 | 7.68 (NA) | 0 | NA | 0 | NA | 0 | NA |
| Benicia Bridge (BBR), SJR Route | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| Benicia Bridge (BBR), OR Route | 1 | 13.36 (NA) | 1 | 4.99 (NA) | 0 | NA | 1 | 4.99 (NA) |
| Benicia Bridge (BBR) | 1 | 13.36 (NA) | 1 | 4.99 (NA) | 0 | NA | 1 | 4.99 (NA) |

Table 24a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon through the San Joaquin River Delta during the 2014 tagging study, excluding predator detections. Standard errors are in parentheses. Reaches beginning at sites with no or too few detections are not shown (i.e., reaches that start at OR4, MRH, MR4, MFE/MFW, and JPE/JPW). See Table 24b for reach travel time with predator-type detections.

| Reach | | Without Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Release 1 | | Release 2 | | Release 3 | | Releases 2, 3 | |
| Upstream Boundary | Downstream Boundary | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Durham Ferry (Release) | DFU | 0 | NA | 0 | NA | 20 | 0.28 (0.05) | 20 | 0.28 (0.05) |
| | DFD | 65 | 0.04 (0.00) | 128 | 0.05 (0.00) | 271 | 0.06 (0.00) | 399 | 0.05 (0.00) |
| DFD | BCA | 20 | 0.29 (0.03) | 10 | 0.48 (0.13) | 41 | 0.36 (0.03) | 51 | 0.38 (0.03) |
| BCA | MOS | 53 | 0.39 (0.02) | 23 | 0.39 (0.04) | 32 | 0.60 (0.08) | 55 | 0.49 (0.04) |
| MOS | SJL | 166 | 0.25 (0.01) | 72 | 0.29 (0.03) | 30 | 0.26 (0.04) | 102 | 0.28 (0.02) |
| | ORE | 17 | 0.37 (0.07) | 7 | 0.58 (0.12) | 2 | 0.26 (0.15) | 9 | 0.46 (0.12) |
| SJL | SJG | 41 | 1.06 (0.08) | 14 | 0.95 (0.19) | 3 | 1.29 (0.39) | 17 | 1.00 (0.18) |
| SJG | SJNB | 28 | 0.09 (0.01) | 9 | 0.08 (0.02) | 1 | 0.46 (NA) | 10 | 0.09 (0.03) |
| | RRI | 2 | 0.31 (0.22) | 3 | 0.22 (0.16) | 0 | NA | 3 | 0.22 (0.16) |
| SJNB | MAC | 2 | 1.35 (0.66) | 1 | 0.42 (NA) | 0 | NA | 1 | 0.42 (NA) |
| | TCE/TCW | 0 | NA | 2 | 0.33 (0.06) | 0 | NA | 2 | 0.33 (0.06) |
| RRI | MAC | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| | TCE/TCW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| ORE | ORS | 9 | 0.41 (0.06) | 4 | 0.20 (0.02) | 2 | 0.28 (0.02) | 6 | 0.22 (0.02) |
| | MRH | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| ORS | OR4 | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| | MR4 | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| | RGU | 1 | 1.57 (NA) | 0 | NA | 0 | NA | 0 | NA |
| | CVP | 2 | 1.27 (0.49) | 1 | 1.12 (NA) | 1 | 1.49 (NA) | 2 | 1.28 (0.18) |
| RGU | RGD | 1 | 0.01 (NA) | 0 | NA | 0 | NA | 0 | NA |
| CVP | CVPtank | 1 | 0.23 (NA) | 1 | 0.09 (NA) | 0 | NA | 1 | 0.09 (NA) |
| MAC | MAE/MAW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| TCE/TCW | | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| RGD | | 0 | NA | 0 | NA | 0 | NA | 0 | NA |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CVPtank | 1 | 2.91 (NA) | 0 | NA | 0 | NA | 0 | NA |

**Table 24a. (Continued)**

| Reach | | Without Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Release 1 | | Release 2 | | Release 3 | | Releases 2, 3 | |
| Upstream Boundary | Downstream Boundary | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| MAC | BBR | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| TCE/TCW | BBR | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| RGD | | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| CVPtank | | 0 | NA | 1 | 2.64 (NA) | 0 | NA | 1 | 2.64 (NA) |
| MAE/MAW | | 0 | NA | 0 | NA | 0 | NA | 0 | NA |

Table 24b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon through the San Joaquin River Delta during the 2014 tagging study, including predator detections. Standard errors are in parentheses. Reaches beginning at sites with no or too few detections are not shown (i.e., reaches that start at OR4, MRH, MR4, MFE/MFW, and JPE/JPW). See Table 24a for reach travel time without predator-type detections.

| Reach | | With Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Release 1 | | Release 2 | | Release 3 | | Releases 2, 3 | |
| Upstream Boundary | Downstream Boundary | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| Durham Ferry (Release) | DFU | 0 | NA | 2 | 6.57 (5.42) | 20 | 0.28 (0.05) | 20 | 0.28 (0.05) |
| | DFD | 77 | 0.05 (0.00) | 134 | 0.05 (0.00) | 27 | 0.06 (0.00) | 399 | 0.05 (0.00) |
| DFD | BCA | 20 | 0.29 (0.03) | 9 | 0.46 (0.14) | 41 | 0.36 (0.03) | 51 | 0.38 (0.03) |
| BCA | MOS | 53 | 0.45 (0.04) | 23 | 0.39 (0.04) | 32 | 0.62 (0.08) | 55 | 0.50 (0.04) |
| MOS | SJL | 165 | 0.25 (0.01) | 73 | 0.29 (0.03) | 30 | 0.29 (0.04) | 103 | 0.29 (0.02) |
| | ORE | 17 | 0.37 (0.07) | 7 | 0.58 (0.12) | 2 | 0.26 (0.15) | 9 | 0.46 (0.12) |
| SJL | SJG | 42 | 1.07 (0.08) | 14 | 0.95 (0.19) | 5 | 1.61 (0.42) | 19 | 1.07 (0.19) |
| SJG | SJNB | 29 | 0.09 (0.01) | 9 | 0.08 (0.02) | 3 | 0.09 (0.05) | 12 | 0.09 (0.02) |
| | RRI | 3 | 0.43 (0.29) | 3 | 0.22 (0.16) | 0 | NA | 3 | 0.22 (0.16) |
| SJNB | MAC | 2 | 1.35 (0.66) | 1 | 35.64 (NA) | 0 | NA | 1 | 35.64 (NA) |
| | TCE/TCW | 0 | NA | 2 | 0.33 (0.06) | 0 | NA | 2 | 0.33 (0.06) |
| RRI | MAC | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| | TCE/TCW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| ORE | ORS | 9 | 0.41 (0.06) | 4 | 0.20 (0.02) | 2 | 0.28 (0.02) | 6 | 0.22 (0.02) |
| | MRH | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| ORS | OR4 | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| | MR4 | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| | RGU | 1 | 1.57 (NA) | 0 | NA | 0 | NA | 0 | NA |
| | CVP | 2 | 1.27 (0.49) | 1 | 1.12 (NA) | 1 | 1.49 (NA) | 2 | 1.28 (0.18) |
| RGU | RGD | 1 | 0.01 (NA) | 0 | NA | 0 | NA | 0 | NA |
| CVP | CVPtank | 1 | 0.23 (NA) | 1 | 0.09 (NA) | 0 | NA | 1 | 0.09 (NA) |
| MAC | MAE/MAW | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| TCE/TCW | | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| RGD | | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| CVPtank | | 1 | 4.56 (NA) | 0 | NA | 0 | NA | 0 | NA |

**Table 24b. (Continued)**

| Reach | | With Predator-Type Detections | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Release 1 | | Release 2 | | Release 3 | | Releases 2, 3 | |
| Upstream Boundary | Downstream Boundary | N | Travel Time | N | Travel Time | N | Travel Time | N | Travel Time |
| MAC | BBR | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| TCE/TCW | BBR | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| RGD | | 0 | NA | 0 | NA | 0 | NA | 0 | NA |
| CVPtank | | 1 | 10.24 (NA) | 1 | 2.64 (NA) | 0 | NA | 1 | 2.64 (NA) |
| MAE/MAW | | 1 | 5.68 (NA) | 0 | NA | 0 | NA | 0 | NA |

**Table 25. Analysis of deviance for group covariates Year and Barrier in the model of route selection at the head of Old River. Residual degrees of freedom and deviance represent the Year x Release x NPBon model, where NPBon indicates the presence of the operating non-physical barrier. NPBon was tested against the year model.**

| Source | Degrees of Freedom | Deviance | Mean Deviance | F-stat | P |
|---|---|---|---|---|---|
| Total (Corrected) | 1,244 | 4233.68 | | | |
| Year | 4 | 821.24 | 205.31 | 56.76 | <0.0001 |
| Physical Barrier | 1 | 638.24 | 638.24 | 176.43 | <0.0001 |
| NPBon\|2010 | 1 | 17.50 | 17.50 | 4.84 | 0.0281 |
| Residual | 928 | 3357.00 | 3.62 | | |

**Table 26. Results of chi-square ($\chi^2$) tests (for individual covariates) or F-tests (for group covariate night) of added effects of single covariates on route selection at the head of Old River for all years, for the model with structure: Year|no-PB + PB + NPBon|Year=2010. All $\chi^2$ tests had 1 degree of freedom. The F test had 1 and 973 degrees of freedom. Covariates are ordered by P-value and test statistic. P-values should be compared to 0.05/15=0.0033 for a familywise Type I error rate of $\alpha$ = 0.05. See Table 34 in Buchanan (2017) for variable names.**

| Covariate | | Significance Test | | |
|---|---|---|---|---|
| Description | Name | Test | Statistic | P |
| 15-minute change in stage at ORE | delC.B.jx | $\chi^2$ | 61.82 | < 0.0001 |
| 15-minute change in stage at SJL | delC.A.jx | $\chi^2$ | 48.83 | < 0.0001 |
| 15-minute change in velocity at ORE | delV.B.jx | $\chi^2$ | 5.69 | 0.0170 |
| Arrive at river junction during day | Day | F | 3.09 | 0.0789 |
| Arrive at river junction during night | Night | F | 2.42 | 0.1204 |
| 15-minute change in flow at ORE | delQ.B.jx | $\chi^2$ | 1.38 | 0.2406 |
| Exports at CVP | CVP.jx | $\chi^2$ | 0.65 | 0.4185 |
| Fork Length | flength | $\chi^2$ | 0.26 | 0.6124 |
| Exports proportion from CVP | pCVP.jx | $\chi^2$ | 0.07 | 0.7904 |
| River stage at ORE | C.B.jx | $\chi^2$ | 0.33 | 0.5655 |
| Combined exports at CVP and SWP | CVSWP.jx | $\chi^2$ | 0.11 | 0.7440 |
| Exports at SWP | SWP.jx | $\chi^2$ | 0.01 | 0.9335 |
| Flow at ORE | Q.B.jx | $\chi^2$ | 0.01 | 0.9171 |
| River stage at SJL | C.A.jx | $\chi^2$ | <0.01 | 0.9766 |
| Velocity at ORE | V.B.jx | $\chi^2$ | <0.01 | 0.9813 |

**Table 27. Results of chi-square ($\chi^2$) tests (for individual covariates) or F-tests (for group covariate night) of added effects of single covariates on route selection at the head of Old River for all years, for the model with structure: Year|no-PB + PB + NPBon|Year=2010 + delC.B.jx. All $\chi^2$ tests had 1 degree of freedom. The F test had 1 and 973 degrees of freedom. Covariates are ordered by P-value and test statistic. P-values should be compared to 0.05/14=0.0036 for a familywise Type I error rate of α = 0.05. See Table 34 in Buchanan (2017) for variable names.**

| Covariate | | Significance Test | | |
|---|---|---|---|---|
| Description | Name | Test | Statistic | P |
| Velocity at ORE | V.B.jx | $\chi^2$ | 4.16 | 0.0412 |
| Flow at ORE | Q.B.jx | $\chi^2$ | 3.99 | 0.0459 |
| River stage at SJL | C.A.jx | $\chi^2$ | 0.92 | 0.3362 |
| River stage at ORE | C.B.jx | $\chi^2$ | 0.91 | 0.3401 |
| Exports at CVP | CVP.jx | $\chi^2$ | 0.88 | 0.3483 |
| Arrive at river junction during day | Day | F | 0.50 | 0.4817 |
| 15-minute change in stage at SJL | delC.A.jx | $\chi^2$ | 0.49 | 0.4833 |
| Arrive at river junction during night | Night | F | 0.37 | 0.5438 |
| Fork Length | Flength | $\chi^2$ | 0.29 | 0.595 |
| 15-minute change in flow at ORE | delQ.B.jx | $\chi^2$ | 0.23 | 0.6339 |
| Combined exports at CVP and SWP | CVSWP.jx | $\chi^2$ | 0.16 | 0.6880 |
| 15-minute change in velocity at ORE | delV.B.jx | $\chi^2$ | 0.10 | 0.7498 |
| Exports proportion from CVP | pCVP.jx | $\chi^2$ | 0.04 | 0.8468 |
| Exports at SWP | SWP.jx | $\chi^2$ | 0.02 | 0.8969 |

**Table 28. Regression coefficient estimates for model of route selection at the head of Old River. Response is probability of selecting Old River route, on logit scale. Standard errors were expanded by the mean residual deviance. Also shown is the *t*-test with 943 degrees of freedom.**

| Parameter | Estimate | SE | z | $P(t_{943}>z)$ |
|---|---|---|---|---|
| Intercept | 0.5418 | 0.2793 | 1.9388 | 0.0528 |
| Effect of 2011 vs 2010 | -0.8536 | 0.2956 | -2.8862 | 0.0040 |
| Effect of 2013 vs 2010 | 0.7805 | 0.3591 | 2.1726 | 0.0301 |
| Effect of Physical Barrier | -3.8982 | 0.4898 | -7.9553 | <0.0001 |
| NPBon for 2010 | -0.7413 | 0.3826 | -1.9366 | 0.0531 |
| delC.B.jx | 8.6493 | 2.1173 | 4.0829 | <0.0001 |

**Table 29. Area under the Curve (AUC) values for the Receiver Operating Characteristic (ROC) curve for models of survival from Mossdale to the head of Old River, using data from the second and third release group from 2014. AUC values > 0.7 indicate acceptable model fit. Model fit was assessed for each year-specific model using models constructed for 2010-2013 in Buchanan (2017). See Table 34 in Buchanan (2017) for variable names.**

| Year Modeled | Covariate | | |
|---|---|---|---|
| | Qvns.1mag | Qvns.1.cdec | Tmsd |
| 2010 | 0.41 | 0.56 | 0.37 |
| 2011 | 0.59 | 0.56 | 0.37 |
| 2012 | 0.41 | 0.44 | 0.37 |
| 2013 | 0.41 | 0.44 | 0.37 |

**Table 30. Analysis of deviance for group covariates Year and Barrier in the known-fate model of survival from MOS to SJL/ORE. Residual degrees of freedom and deviance represent the Year x Release x NPBon model, where NPBon indicates the presence of the operating non-physical barrier. NPBon was tested against the year model.**

| Source | Degrees of Freedom | Deviance | Mean Deviance | F-stat | P |
|---|---|---|---|---|---|
| Total (Corrected) | 262 | 1795.50 | | | |
| Year | 4 | 265.51 | 66.38 | 11.25 | < 0.0001 |
| Physical Barrier | 1 | 91.53 | 91.53 | 15.51 | 0.0001 |
| NPBon\|2010 | 1 | 4.68 | 4.68 | 0.79 | 0.3742 |
| Residual | 239 | 1410.13 | 5.90 | | |

**Table 31. Results of chi-square ($\chi^2$) tests (for individual covariates) or F-tests (for group covariates day and night) of added main and interaction effects with Year for single covariates on survival from Mossdale to the head of Old River and detection at SJL and ORE receivers for the model with structure: Year. All $\chi^2$ tests had 5 degrees of freedom. The F tests had 5 and either 243 (for Day) or 244 (for Night) degrees of freedom. Covariates are ordered by P-value and test statistic. P-values should be compared to 0.05/7=0.0071 for a familywise Type I error rate of α = 0.05. The smallest Akaike information criterion (AIC) and those that were within 2 of the smallest AIC, are bolded. Variable names refer to Table 34 in Buchanan (2017). Asterisk indicates data missing for 1 observation (AIC should not be compared to other covariates).**

| Covariate | | Significance Test | | | |
|---|---|---|---|---|---|
| Description | Name | Test | Statistic | P | AIC |
| 1-day average magnitude of SJR flow at VNS from release date | Qvns.1mag | $\chi^2$ | 78.69 | < 0.0001 | **1471.31** |
| 1-day average daily mean of SJR flow at VNS from departure from MOS | Qvns.1.cdec | $\chi^2$ | 75.83 | < 0.0001 | 1474.16 |
| 1-day average temperature at MSD | Tmsd | $\chi^2$ | 54.79 | <0.0001 | 1495.21 |
| 1-day standard deviation of SJR flow at VNS | Qvns1.SD | $\chi^2$ | 10.22 | 0.0692 | 1539.78 |
| Depart MOS during day | Day | F | 0.92 | 0.4718 | 1521.72 |
| Depart MOS during night | Night | F | 0.88 | 0.4938 | 1522.84 |
| Fork Length | flength* | $\chi^2$ | 4.23 | 0.5172 | 1545.66 |

**Table 32. Results of chi-square ($\chi^2$) tests of the interaction effect with Year for single covariates (X) on survival from Mossdale to the head of Old River and detection at SJL and ORE receivers, for models with structure: Year + X, for covariate X. All tests had 1 degree of freedom. Only those covariates found to be significant in Table 31 were included; covariates are ordered according to Table 31. P-values should be compared to 0.05/3=0.0167 for a familywise Type I error rate of α = 0.05. The smallest AIC, and those that were within 2 of the smallest AIC, are bolded. Variable names refer to Table 34 in Buchanan (2017).**

| Covariate | | Significance Test: Interaction effect | | AIC | |
|---|---|---|---|---|---|
| Description | Name | Statistic | P | Year + X | Year*X |
| 1-day average magnitude of SJR flow at VNS from release date | Qvns.1mag | 71.47 | <0.0001 | 1534.78 | **1471.31** |
| 1-day average daily mean of SJR flow at VNS from departure from MOS | Qvns.1.cdec | 68.23 | <0.0001 | 1534.40 | 1474.16 |
| 1-day average temperature at MSD | Tmsd | 45.49 | <0.0001 | 1532.70 | 1495.21 |

**Table 33. Results of chi-square ($\chi^2$) tests (for individual covariates) or F-tests (for group covariates day and night) of added main effects of single covariates on survival from Mossdale to the head of Old River and detection at SJL and ORE receivers for the model with structure: Year x Qvns.1mag. All $\chi^2$ tests had 1 degree of freedom. The F tests had 1 and either 242 (for Day) or 243 (for Night) degrees of freedom. Covariates are ordered by P-value and test statistic. P-values should be compared to 0.05/6=0.0083 for a familywise Type I error rate of α = 0.05. Variable names refer to Table 34 in Buchanan (2017). Asterisk indicates data missing for 1 observation (AIC should not be compared to other covariates).**

| Covariate | | Significance Test | | | |
|---|---|---|---|---|---|
| Description | Name | Test | Statistic | P | AIC |
| 1-day standard deviation of SJR flow at VNS | Qvns1.SD | $\chi^2$ | 7.03 | 0.0080 | **1466.28** |
| Fork Length | flength* | $\chi^2$ | 1.39 | 0.2390 | 1471.67 |
| Depart MOS during night | Night | F | 0.95 | 0.3312 | 1467.67 |
| 1-day average daily mean of SJR flow at VNS | Qvns.1.cdec | $\chi^2$ | 0.94 | 0.3316 | 1472.37 |
| Depart MOS during day | Day | F | 0.58 | 0.4472 | 1469.84 |
| 1-day average temperature at MSD | Tmsd | $\chi^2$ | 0.11 | 0.7362 | 1473.20 |

**Table 34. Results of chi-square ($\chi^2$) tests (for individual covariates) or F-tests (for group covariates day and night) of added main effects of single covariates on survival from Mossdale to the head of Old River and detection at SJL and ORE receivers for the model with structure: Year x Qvns.1mag+Qvns1.SD. All $\chi^2$ tests had 1 degree of freedom. The F tests had 1 and either 241 (for Day) or 242 (for Night) degrees of freedom. Covariates are ordered by P-value and test statistic. P-values should be compared to 0.05/5=0.0100 for a familywise Type I error rate of α = 0.05. Variable names refer to Table 34 in Buchanan (2017). Asterisk indicates data missing for 1 observation (AIC should not be compared to other covariates).**

| Covariate | | Significance Test | | | |
|---|---|---|---|---|---|
| Description | Name | Test | Statistic | P | AIC |
| Fork Length | flength* | $\chi^2$ | 1.94 | 0.1641 | 1466.09 |
| Depart MOS during night | Night | F | 0.71 | 0.3997 | 1464.04 |
| 1-day average daily mean of SJR flow at VNS | Qvns.1.cdec | $\chi^2$ | 0.53 | 0.4680 | 1467.75 |
| Depart MOS during day | Day | F | 0.41 | 0.5201 | 1465.80 |
| 1-day average temperature at MSD | Tmsd | $\chi^2$ | 0.03 | 0.8567 | 1468.24 |

**Table 35. Comparison of known fate models for survival from Mossdale to head of Old River and detection at SJL or ORE. AUC = area under the receiver operating characteristic curve. Values of AUC > 0.7 are considered acceptable.**

| Model | Individual-based Covariate | Number of parameters | AIC | AUC |
|---|---|---|---|---|
| M1.Smos | Qvns.1mag, Qvns1.SD | 11 | 1466.28 | 0.7947 |
| M2.Smos | Qvns.1mag | 10 | 1471.31 | 0.7876 |

**Table 36. Regression coefficient estimates for known fate models of survival from Mossdale to the head of Old River. Response is the joint probability of surviving from Mossdale to the head of Old River and detection at either SJL or ORE, on logit scale. Standard errors (SE) were expanded by the mean residual deviance for each model. Also shown is the *t*-test with df = 252 degrees of freedom for model M1.Smos, or df = 253 degrees of freedom for model M2.Smos.**

| Model | Parameter | Estimate | SE | z | $P(t_{df}>z)$ |
|---|---|---|---|---|---|
| M1.Smos | Intercept for 2010 | 2.2361 | 4.0155 | 0.5569 | 0.5781 |
| | Intercept for 2011 | 18.8957 | 8.3875 | 2.2528 | 0.0251 |
| | Intercept for 2012 | -3.5807 | 4.1957 | -0.8534 | 0.3942 |
| | Intercept for 2013 | 0.1423 | 1.0053 | 0.1415 | 0.8876 |
| | Intercept for 2014 | 2.4127 | 2.1768 | 1.1084 | 0.2688 |
| | Qvns.1mag for 2010 | -0.00002 | 0.0008 | -0.0302 | 0.9859 |
| | Qvns.1mag for 2011 | -0.0015 | 0.0008 | -1.9296 | 0.0548 |
| | Qvns.1mag for 2012 | 0.0023 | 0.0016 | 1.4607 | 0.1454 |
| | Qvns.1mag for 2013 | 0.0009 | 0.0005 | 2.0975 | 0.0369 |
| | Qvns.1mag for 2014 | -0.0011 | 0.0009 | -1.1875 | 0.2362 |
| | Qvns1.SD | 0.0035 | 0.0040 | 0.8706 | 0.3848 |
| M2.Smos | Intercept for 2010 | 2.2044 | 4.1224 | 0.5348 | 0.5933 |
| | Intercept for 2011 | 17.7968 | 8.2867 | 2.1476 | 0.0327 |
| | Intercept for 2012 | -3.4445 | 4.2257 | -0.851 | 0.4158 |
| | Intercept for 2013 | 0.2643 | 0.9983 | 0.2648 | 0.7914 |
| | Intercept for 2014 | 2.7156 | 2.1229 | 1.2792 | 0.2020 |
| | Qvns.1mag for 2010 | 0.00002 | 0.0008 | 0.0296 | 0.9764 |
| | Qvns.1mag for 2011 | -0.0014 | 0.0008 | -1.7973 | 0.0735 |
| | Qvns.1mag for 2012 | 0.0023 | 0.0016 | 1.4405 | 0.1510 |
| | Qvns.1mag for 2013 | 0.0009 | 0.0005 | 2.0913 | 0.0375 |
| | Qvns.1mag for 2014 | -0.0001 | 0.0009 | -1.2552 | 0.2106 |

**Table 37. Chipps Island detection probability models. Model structure is logit($p_{ji}$)=$\beta_{0j}$+$\beta_{1j}$QOUT$_i$, for receiver line *j*=1,2, and individual tag *i*. Common intercept: $\beta_{01}$=$\beta_{02}$. Common QOUT effect: $\beta_{11}$=$\beta_{12}$.**

| Model | Intercept | QOUT effect | AIC |
|---|---|---|---|
| $M_{p0}$ | Common | None | 761.12 |
| $M_{p1}$ | Unique | None | 759.27 |
| $M_{p2}$ | Common | Common | 758.21 |

**Table 38. Analysis of deviance for group covariates Route and Barrier in the model of survival from SJL/ORE to Chipps Island. Residual degrees of freedom and deviance represent a maximal model that estimated unique survival probabilities for each combination of year, release group, route, and non-physical barrier status, with year pooled for the drought years of 2012 through 2014. NPBon indicates the presence of the operating non-physical barrier.**

| Source | Degrees of Freedom | Deviance | Mean Deviance | F-stat | P |
|---|---|---|---|---|---|
| Total (Corrected) | 74 | 784.88 | | | |
| Route | 1 | 12.64 | 12.64 | 0.77 | 0.3853 |
| Physical Barrier | 1 | 0.02 | 0.02 | 0.001 | 0.9705 |
| NPBon\|2010 | 1 | 2.93 | 2.93 | 0.18 | 0.6749 |
| Residual | 41 | 673.13 | 16.42 | | |

Table 39. Results of chi-square ($\chi^2$) tests of combined added main effects and interaction effects with route of single covariates on survival from the head of Old River to Chipps Island, for model with route effects. All tests had 2 degrees of freedom. Covariates are ordered by P-value, test statistic, and AIC. P-values should be compared to 0.05/22=0.0023 for a familywise Type I error rate of $\alpha = 0.05$. The smallest AIC, and those that were within 2 of the smallest AIC, are bolded. Variable names refer to Table 34 in Buchanan (2017). Asterisk indicates data missing for 1 observation; AIC should not be compared to other covariates. Double asterisk indicates data missing for 41 observations; AIC should not be compared to other covariates.

| Covariate | | Significance Test | | |
|---|---|---|---|---|
| Description | Name | Statistic | P | AIC |
| 3-day RMS of Old River flow at ORB | Qorb.ore.3rms | 39.92 | <0.0001 | **744.32** |
| 3-day RMS of OMR flow | Qomr.ore.3rms* | 33.69 | <0.0001 | 750.52 |
| 3-day RMS of Middle River flow at MID | Qmid.ore.3rms | 25.06 | <0.0001 | 759.18 |
| 2-day average daily export rate at CVP | CVP.2 | 12.86 | 0.0016 | 771.38 |
| 2-day average of combined export rate | CVPSWP.2 | 12.00 | 0.0025 | 772.24 |
| 2-day average daily export rate at SWP | SWP.2 | 11.08 | 0.0039 | 773.16 |
| 2-day RMS of SJR flow at BDT | Qbdt.sjl.2rms** | 10.09 | 0.0064 | 772.6 |
| 2-day average of net SJR flow at BDT | Qbdt.sjl.2net** | 9.83 | 0.0073 | 772.86 |
| 3-day average of net Old River flow at OH1 | Qoh1.ore.3net | 9.80 | 0.0074 | 774.44 |
| 3-day RMS of Old River flow at OH1 | Qoh1.ore.3rms | 9.80 | 0.0074 | 774.44 |
| 4-day average of net SJR flow at VNS | Qvns.rel.4net | 9.36 | 0.0093 | 774.88 |
| 4-day average daily mean SJR flow at VNS | VNS.4 | 9.22 | 0.0100 | 775.02 |
| 2-day average daily mean SJR flow at VNS | VNS.2 | 9.17 | 0.0102 | 775.07 |
| 3-day average of net Middle River at MID | Qmid.ore.3net | 9.12 | 0.0104 | 775.12 |
| 3-day average of net OMR flow | Qomr.ore.3net* | 8.99 | 0.0112 | 775.21 |
| 3-day average of net Old River flow at ORB | Qorb.ore.3net | 8.74 | 0.0126 | 775.5 |
| Fork Length | flength* | 5.05 | 0.0801 | 34.84 |
| 2-day average of X2 | X2.2 | 3.86 | 0.1448 | 36.05 |
| CVP proportion of Exports | pCVP.2 | 2.94 | 0.2294 | 781.3 |
| 2-day average daily mean I:E ratio | IE.2 | 2.00 | 0.3679 | 782.24 |
| 2-day average of temperature at SJL | Tsjl.2 | 1.33 | 0.5155 | 782.91 |
| 2-day average of temperature at OH1 | Toh1.2 | 0.89 | 0.6401 | 783.35 |

**Table 40. Results of chi-square ($\chi^2$) tests of the interaction effect with route of single covariates (X) on survival from the head of Old River to Chipps Island, for models with structure: Route + X, for covariate X. All tests had 1 degree of freedom. Only those covariates found to be significant in Table 39 were included; covariates are ordered according to Table 39. P-values should be compared to 0.05/4=0.0125 for a familywise Type I error rate of α = 0.05. The smallest AIC, and those that were within 2 of the smallest AIC, are bolded. Variable names refer to Table 34 in Buchanan (2017). Asterisk indicates data missing for 41 observations; AIC should not be compared to other covariates.**

| Covariate | | Significance Test: Interaction effect | | AIC | |
|---|---|---|---|---|---|
| Description | Name | Statistic | P | Route + X | Route*X |
| 3-day RMS of Old River flow at ORB | Qorb.ore.3rms | 0.29 | 0.5896 | **742.61** | **744.32** |
| 3-day RMS of OMR flow | Qomr.ore.3rms* | 1.10 | 0.2934 | 749.62 | 750.52 |
| 3-day RMS of Middle River flow at MID | Qmid.ore.3rms | 1.85 | 0.1737 | 759.03 | 759.18 |
| 2-day average daily export rate at CVP | CVP.2 | 11.07 | 0.0009 | 780.46 | 771.38 |

Table 41. Results of chi-square ($\chi^2$) tests of combined added main effects and interaction effects with route on survival from the head of Old River to Chipps Island, for model with structure: Route + Qorb.ore.3rms. All tests had 2 degrees of freedom. Covariates are ordered by P-value, test statistic, and AIC. P-values should be compared to 0.05/21=0.0024 for a familywise Type I error rate of α = 0.05. Variable names refer to Table 34 in Buchanan (2017). Asterisk indicates data missing for 1 observation; AIC should not be compared to other covariates. Double asterisk indicates data missing for 41 observations; AIC should not be compared to other covariates.

| Covariate | | Significance Test | | |
|---|---|---|---|---|
| Description | Name | Statistic | P | AIC |
| 2-day RMS of SJR flow at BDT | Qbdt.sjl.2rms** | 8.80 | 0.0123 | 737.05 |
| 2-day average daily export rate at SWP | SWP.2 | 8.40 | 0.0150 | 738.21 |
| CVP proportion of Exports | pCVP.2 | 8.34 | 0.0154 | 738.27 |
| 2-day average of combined export rate | CVPSWP.2 | 8.23 | 0.0163 | 738.38 |
| 2-day average of net SJR flow at BDT | Qbdt.sjl.2net** | 8.12 | 0.0172 | 737.73 |
| 2-day average daily export rate at CVP | CVP.2 | 7.04 | 0.0295 | 739.57 |
| 4-day average daily mean SJR flow at VNS | VNS.4 | 5.36 | 0.0684 | 741.25 |
| Fork Length | flength* | 5.32 | 0.0698 | 741.26 |
| 2-day average daily mean SJR flow at VNS | VNS.2 | 5.27 | 0.0717 | 741.34 |
| 4-day average of net SJR flow at VNS | Qvns.rel.4net | 5.18 | 0.0749 | 741.43 |
| 3-day average of net Middle River at MID | Qmid.ore.3net | 4.56 | 0.1022 | 742.05 |
| 2-day average of temperature at SJL | Tsjl.2 | 4.44 | 0.1085 | 742.17 |
| 2-day average of temperature at OH1 | Toh1.2 | 4.24 | 0.1199 | 742.37 |
| 3-day RMS of Old River flow at OH1 | Qoh1.ore.3rms | 4.21 | 0.1220 | 742.4 |
| 3-day average of net Old River flow at OH1 | Qoh1.ore.3net | 4.20 | 0.1225 | 742.41 |
| 3-day average of net OMR flow | Qomr.ore.3net* | 4.20 | 0.1226 | 742.38 |
| 3-day average of net Old River flow at ORB | Qorb.ore.3net | 3.75 | 0.1537 | 742.87 |
| 3-day RMS of Middle River flow at MID | Qmid.ore.3rms | 2.98 | 0.2257 | 743.63 |
| 3-day RMS of OMR flow | Qomr.ore.3rms* | 2.52 | 0.2837 | 744.06 |
| 2-day average of X2 | X2.2 | 1.84 | 0.3990 | 744.77 |
| 2-day average daily mean I:E ratio | IE.2 | 0.83 | 0.6617 | 745.79 |

**Table 42. Regression coefficient estimates for route effects model of survival from the head of Old River to Chipps Island, with structure S ~ Route + $Q_{ORB}$. Response is probability of survival to Chipps Island, on logit scale. Standard errors (SE) have been expanded by the mean residual deviance. Also shown is the *t*-test with 72 degrees of freedom.**

| Component | Parameter | Estimate | SE | z | $P(t_{72}>z)$ |
|---|---|---|---|---|---|
| Survival | Intercept (San Joaquin River Route) | -14.7448 | 6.0695 | -2.4293 | 0.0176 |
| Survival | Effect of Old River Route vs SJR Route | 1.0878 | 0.7771 | 1.3997 | 0.1659 |
| Survival | Qorb.ore.3rms | 0.0011 | 0.0006 | 1.8139 | 0.0739 |
| Detection | Intercept | 4.6902 | 3.6043 | 1.3013 | 0.1973 |
| Detection | QOUT | -0.0001 | 0.0001 | -0.6814 | 0.4978 |

**Table 43: Estimates of survival between SJL and RS7 ($\sigma_{A5}$) and between RS7 and SJG ($\sigma_{A6}$), and detection probability at RS7 ($P_{N4}$), for acoustic-tagged juvenile Chinook Salmon released in 2014, with and without predator-type detections. Standard errors are in parentheses. Survival estimates are adjusted for tag failure for release groups 2 and 3.**

| Parameter | Release Group (Without Predators) | | | Release Group (With Predators) | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| $\sigma_{A5}$ | 0.42 (0.04) | 0.35 (0.06) | 0.40 (0.09) | 0.43 (0.04) | 0.37 (0.06) | 0.37 (0.09) |
| $\sigma_{a6}$ | 0.58 (0.06) | 0.56 (0.10) | 0.25 (0.12) | 0.57 (0.06) | 0.52 (0.10) | 0.46 (0.15) |
| $P_{N4}$ | 1 | 1 | 1 | 1 | 1 | 1 |

# Appendices

## Appendix A

# Sample Size Simulations Analysis for 2014 Chinook Acoustic-Tagging Study

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**Summary of Results** With survival from Durham Ferry to Chipps Island as low as 0.007, a single release of 648 fish at Durham Ferry is expected to yield admissible estimates of overall survival and route-specific survival in the San Joaquin River route, with SE ≤ 0.1, approximately 95% of the time. Estimation of route-specific survival in the Old River route or estimates with higher precision will require much larger release sizes in the presence of highly effective barrier at the head of Old River. It is recommended that objectives be focused on the San Joaquin River route survival. Little is gained, and some precision is lost, by dividing the release into a Durham Ferry release with a supplemental release at Stockton.

**Methods**

Data were simulated using the same model as in previous sample size simulations (i.e., for 2010 study), with parameter values reflecting low but positive survival probabilities, high detection probabilities, and an effective barrier at the head of Old River.

Criteria considered for a successful study are listed in Table A1. A revised C1 criterion was also considered that required the parameter to be estimable in at least 99% of the simulations (1980 or more of 2000 simulations). The C2 criterion is generally not applicable here because survival probabilities are very low. A more stringent C3 criterion was also considered, requiring SE ≤ 0.05.

**Table A1. Criteria used for identification of minimum sample size necessary to estimate a model parameter, assuming 2000 simulations.**

| Criterion | Definition |
|---|---|
| C1 | Parameter is estimable in at least 95% of simulations (1900 or more) |
| C2 | Probability estimate is not greater than 1.1 in 95% of simulations (1900 or more) |
| C3 | Standard error on parameter estimate is not greater than 0.10 |

Estimable parameters are:

- SR = survival from Durham Ferry to Chipps Island (assumed = 0.007 – 0.12)
- SRO = survival from Durham Ferry to the head of Old River (assumed = 0.35 – 0.80)
- SA = survival from Lathrop to Chipps Island in San Joaquin River route (assumed = 0.02 – 0.15)
- SB = survival from Old River East to Chipps Island in Old River route (assumed = 0.02 – 0.15)
- ψA = route entrainment into the San Joaquin River at the head of Old River (assumed = 0.98)

Other parameters:

- pA3 = probability of detection at Lathrop (either line in dual array) (assumed = 0.99)
- pB1 = probability of detection at Old River East (either line in dual array) (assumed = 0.99)
- P = probability of detection at Chipps Island (either line in dual array) (assumed = 0.8 – 0.99)

**Results**

With only a single release at Durham Ferry and assuming the large majority of fish reaching the head of Old River remain in Old River, a release size of 648 should be sufficient to estimate overall survival to Chipps Island and via the San Joaquin River route 95% of the time. However, because very few fish are expected to enter the Old River route under this scenario, a much larger release group (2000) would be necessary to estimate survival to Chipps Island via the Old River route (Table A2). Using a supplemental release at Stockton of 160 with the remaining 488 fish released at Durham Ferry should be sufficient to estimate survival to Chipps Island via the San Joaquin River Route (Table A3).

Using a more stringent criterion of getting parameter estimates 99% of the time generally required larger sample sizes than available. In order to estimate $S_R$, $S_{RO}$, $S_A$, and $\psi_A$ with 99% success rate from a single release at Durham Ferry, 1000 fish would need to be released (results not shown). Using a supplemental release at Stockton generally made more parameters estimable (99% of time) at a Durham Ferry release size of 400 and supplemental release size of 160, as long as survival was not very low (results not shown). However, using a supplemental release also tended to decrease precision (see below).

With a single release of 648 at Durham Ferry, the expected coefficient of variation on the survival estimates depends on the survival probability to Chipps Island. At lower survival levels, the CV on overall survival to Chipps Island ($S_R$) may be as high as 0.45 (i.e., 45%); at relatively high survival levels (e.g., $S_R$=0.12), the CV is expected to be approximately 0.11 (Table A4). CV's on estimates of route-specific survival for the San Joaquin River route are expected to comparable to those on overall survival; estimates in the Old River route will have lower precision (higher CV), as expected with an effective barrier in place. In general, it is better to have a lower CV (<0.5); in particular, an estimate with CV = 0.5 will have a 95% confidence interval that includes 0.

With a release of 488 at Durham Ferry and a supplemental release of 160 at Stockton, the CV values increase slightly on all estimates (Table A5).

**Table A2. Release size at Durham Ferry necessary to estimate parameters (i.e., get point estimate > 0 95% of the time, SE < 0.1).**

| Scenario | $S_R$ | $S_{RO}$ | $S_A$ | $S_B$ | $\psi_A$ |
|---|---|---|---|---|---|
| $S_R$ = 0.007, $\psi_A$ = 0.98 | 648 | 488 | 648 | 2000 | 488 |
| $S_R$ = 0.017, $\psi_A$ = 0.98 | 400 | 488 | 400 | 2000 | 488 |
| $S_R$ = 0.050, $\psi_A$ = 0.98 | 400 | 400 | 400 | 2000 | 400 |
| $S_R$ = 0.120, $\psi_A$ = 0.98 | 400 | 400 | 400 | 2000 | 400 |

**Table A3. Size of initial release at Durham Ferry and supplemental release at Stockton necessary to estimate parameters (i.e., get point estimate > 0 95% of the time, SE < 0.1).**

| Scenario | $S_R$ | $S_{RO}$ | $S_A$ | $S_B$ | $\psi_A$ |
|---|---|---|---|---|---|
| $S_R$ = 0.007, $\psi_A$ = 0.98 | 648; 0 | 488; 0 | 400; 160 | 2000; 0 | 488; 0 |
| $S_R$ = 0.017, $\psi_A$ = 0.98 | 400; 0 | 488; 0 | 400; 0 | 2000; 0 | 488; 0 |
| $S_R$ = 0.050, $\psi_A$ = 0.98 | 400; 0 | 400; 0 | 400; 0 | 2000; 0 | 400; 0 |
| $S_R$ = 0.120, $\psi_A$ = 0.98 | 400; 0 | 400; 0 | 400; 0 | 2000; 0 | 400; 0 |

**Table A4. Expected coefficient of variation (CV) of estimates using a single release of 648 fish at Durham Ferry.**

| Scenario | $S_R$ | $S_{RO}$ | $S_A$ | $S_B$ | $\psi_A$ |
|---|---|---|---|---|---|
| $S_R$ = 0.007, $\psi_A$ = 0.98 | 0.45 | 0.05 | 0.44 | 0.62 | 0.01 |
| $S_R$ = 0.017, $\psi_A$ = 0.98 | 0.30 | 0.05 | 0.30 | 0.56 | 0.03 |
| $S_R$ = 0.050, $\psi_A$ = 0.98 | 0.20 | 0.04 | 0.19 | 0.50 | 0.01 |
| $S_R$ = 0.120, $\psi_A$ = 0.98 | 0.11 | 0.02 | 0.11 | 0.56 | 0.01 |

**Table A5. Expected coefficient of variation (CV) of estimates using a release of 488 fish at Durham Ferry and a supplemental release of 160 at Stockton.**

| Scenario | $S_R$ | $S_{RO}$ | $S_A$ | $S_B$ | $\psi_A$ |
|---|---|---|---|---|---|
| $S_R$ = 0.007, $\psi_A$ = 0.98 | 0.49 | 0.06 | 0.49 | 0.50 | 0.03 |
| $S_R$ = 0.017, $\psi_A$ = 0.98 | 0.35 | 0.06 | 0.35 | 0.35 | 0.04 |
| $S_R$ = 0.050, $\psi_A$ = 0.98 | 0.22 | 0.05 | 0.22 | 0.26 | 0.01 |
| $S_R$ = 0.120, $\psi_A$ = 0.98 | 0.13 | 0.22 | 0.13 | 0.20 | 0.07 |

## Standard Operating Procedure

# Acoustic Tagging for Steelhead 2014 South Delta Studies

## MATERIALS NEEDED:

- Dissolved oxygen (DO) meter (e.g., YSI 85)
- Acoustic tags (V-5)
- VEMCO acoustic tag activator
- VEMCO acoustic tag verification equipment (VR-100)
- 14 day pill boxes for tag distribution
- Chlorhexidine solution (Nolvasan; 30 mL/L D-$H_2O$)
- Distilled or de-ionized water (D-$H_2O$)
- Aqui-S 20E (undiluted, directly from manufacturer)
- Stress coat—stock concentration and 25% solution (250 mL/L D-$H_2O$)
- Disinfectant solution (Virkon Aquatic or 70% EtOH)
- 19 L bucket(s) marked at 10 L and clearly labeled ‘Anesthesia’
- 19 L buckets clearly labeled ‘Reject’ for fish not selected for tagging procedures
- 19 L buckets clearly labeled ‘Lethal’ for fish that need to be euthanized
- 19 L buckets for post-surgical recovery of fish
- Two gravity feed containers marked at 10 L, and connected by rubber tubing with in-line shut-off valves (one labeled ‘Anesthesia’ and one labeled ‘Freshwater’)
- Designated syringes (5 mL) for measuring anesthetic and stress coat
- Oxygen delivery system (cylinder, regulator, airline, air diffusers) for recovery buckets
- Dip nets
- Sanctuary nets
- Nitrile gloves (in all sizes)
- Scale measuring to the nearest 0.1 g (weighing fish)
- Scale measuring to the nearest 0.001 g (weighing tags)
- Large plastic weigh boats or Tupperware container to weigh fish
- Measuring board with ruler to the nearest millimeter
- Surgical platform (cradle)

- Autoclave
- Trays for holding solutions used to disinfect surgical tools
- Trays to rinse disinfected tools
- Needle drivers (multiple sets)
- Forceps (multiple sets)
- Scalpel handle and blades (multiple sets)
- Scissors (multiple sets)
- Tissue collection supplies: scissors, blotter paper, labeled coin envelopes
- Sutures: Vicryl plus 4-0 with an RB-1 needle
- Spray bottles for disinfectant solution
- Timer(s)
- Sharps container
- Datasheets, clipboards, and writing tools
- Clip on tag labels to identify fish in recovery buckets
- Clean rags for keeping tagging areas clean and dry
- Aerators for bucket use (surgeon recovery bucket, recovery at code out)

*Pre-tagging Activities:*

- All acoustic tags will be weighed to the nearest 0.001 g
- All acoustic tags need to be soaked for a minimum of 24 h prior to surgery in a saline solution to ensure that the tags are waterproof, and that the seals encapsulating the tags are functional.
- Rinse, dry, and activate transmitters the day before they are to be implanted. Confirm operational status with the VEMCO tag activator and record the date and time when a tag is activated

*Equipment Set up:*

- Remove transport containers from the freezer and prepare them to receive tagged fish
  - Transport containers that leave the hatchery grounds and are delivered to the release site at Durham Ferry must be frozen for at least 24 h prior to being used again for the tagging operation. These details are outlined in the project Biosecurity Plan
  - When removing containers from the freezer, be sure to consult with the tagging coordinator to ensure that all containers undergo the minimum 24 h of exposure before they are removed and used
- Prepare the transport truck to be able to circulate water through containers
- Water temperatures during all aspects of the tagging operations cannot exceed 2° C difference from the reference water source (for this study, the raceway where source fish are held)

  - Anesthesia buckets, gravity feed carboys, recovery buckets, and totes should not be filled until near the time they are needed to avoid warming
  - Anesthesia buckets and gravity feed carboys should be replaced regularly to prevent increasing water temperatures over time
- Fill disinfection trays for surgical instruments with Nolvasan
- Fill rinse tray with de-ionized or distilled water
- Fill pill boxes containing study tags with Nolvasan and allow at least 20 min of contact time with the disinfectant. Following disinfection, thoroughly rinse transmitters in distilled or de-ionized water prior to implantation. Transmitters should only be handled by gloved hands or clean surgical instruments such as forceps following the disinfection step.
- Set up and calibrate scale, measuring board, and surgical platform
- Fill gravity feed carboys with water from raceway
  - Add 1 mL Aqui-S 20E to the 10 L of water in the anesthesia carboy and briefly agitate to ensure dispersal
  - The freshwater carboy is filled from the raceway and has no anesthesia added
- Fill anesthesia bucket to 10 L line with water from source tank or raceway. Add 3 mL Aqui-S 20E and briefly agitate to ensure dispersal. Cover with a lid
- Adding Aqui-S 20E to any container should be done carefully, with communication between the surgeon and the assistant to avoid double dose or no dose outcomes.
- Retrieve a 5 gallon fish recovery bucket filled with water from the raceway that has been supersaturated with 130–150% oxygen. Add stress coat
- Reference Tag and Tote inventory sheet and retrieve clip-on tag ID labels for recovery buckets to be used during tag operations
- Check that a reject bucket has been filled with water from the source tank or raceway and is outfitted with an air bubbler
- Check that a clearly labeled lethal bucket is ready for fish that need to be euthanized. This bucket should be positioned well away from the tagging stations to ensure that it is not confused with an anesthesia bucket.
- Start a tag data sheet and a daily fish reject tally datasheet for each tagging station to account for fish that are handled but not tagged
- The surgeon should wear clean medical grade exam gloves during all procedures that involve handling fish

*Surgical Implantation of the transmitter:*

- Food should be withheld from fish for ~24 h prior to surgical implantation of the transmitter.

- **Anesthetize fish and collect morphometric data:**

- Net one fish from raceway using a sanctuary net and place directly into an anesthesia bucket.
    - Use a standard net inside the sanctuary net to avoid adding water to the anesthesia bucket and diluting the working concentration of the Aqui-S 20E.
    - Start a stopwatch immediately after the fish has been placed into the anesthesia bucket in order to track how long the fish is exposed to anesthesia
    - Place a lid on the bucket and deliver the bucket to a tagging station.
- Remove the lid after about 1 min to observe the fish for loss of equilibrium. Keep the fish in the water for an additional 30–60 s after it has lost equilibrium.
    - Time of sedation should normally be 2–4 min, with an average of about 3 min.
    - If loss of equilibrium takes less than 1 min or if a fish is in the anesthesia bucket for more than 5 min, reject that fish.
    - If after sedating a few fish, if they are consistently losing equilibrium in more or less time than typical, the anesthesia concentration may need to be adjusted. This should only be done after consultation with the tag coordinator, and should be done in 0.5 mL increments. Concentration changes should be executed for all surgeons simultaneously and recorded on the tagging datasheet
- If a fish is unacceptable for tagging, place the fish in the reject bucket, inform the data recorder, and record it on the daily reject tally sheet
- Record fish fork length, weight, and scale condition:
    - Start "air time" timer when a fish is removed from the anesthesia bucket
    - Transfer the fish to the scale and weigh to the nearest 0.1 g.
        - A fish is acceptable for tagging if it weighs at least 13 g, so that the tag burden does not exceed 5% of the weight of the fish. The transmitters used for this study are Vemco brand, model V5, which weigh about 0.65 g in air
        - In order to keep study fish in a reasonable size range, representing the average fish reared at the hatchery, fish will not be tagged fish they weigh 200 g or more (i.e., fish that weigh 199 g can be tagged, fish at 200 g should be rejected)
    - Transfer the fish to the measuring board. Measure fork length (FL) to the nearest mm
    - Check for any abnormalities and descaling
        - A fish is acceptable for tagging when it lacks deformations such as non-normal color, gross anatomical deformations, damaged opercula with exposed gill filaments, gross scarring, bleeding scratches, any bulging eyes, gross signs of disease, any fungal infection, or any fin hemorrhaging
        - Scale condition is noted as Normal (N), Partial (P), or Descaled (D) and is assessed on the most compromised side of each fish. The normal scale condition is defined as loss of less than 5% of scales on one side of the fish. Partial descaling is defined as loss of 6–19% of scales on one side of the fish. Fish are classified as descaled if they have lost 20% or more of

the scales on one side of the fish, and should not be tagged due to compromised osmoregulatory ability.

- Data must be vocally relayed to the recorder and the recorder should repeat the information back to the surgeon to avoid miscommunication
- Any fish dropped on the floor should be rejected. Fish dropped from the surgical platform to the table or working surface may be advanced through the tagging process or rejected based on the surgeon's evaluation of the fish.
- The anesthesia containers should be emptied and remixed at regular intervals throughout the tagging operation to ensure the appropriate concentration and to avoid warming
- The gravity feed containers should be monitored for volume and temperature and changed as needed to avoid inadequate volume to complete a surgery and significant warming (difference in water temperature from the raceway cannot exceed 2° C)

- **Transmitter implantation:**
  - Place the fish into the surgical platform ventral side up.
  - Anesthesia should be administered through the gravity feed tube as soon as the fish is on the surgery platform. Using the in-line valve, adjust the flow as needed so that the gilling rate of the fish is steady
  - Remove a 2 mm by 2 mm section of the ventral portion of the caudal fin and place on filter paper. Put filter paper in pre-labeled coin envelopes that indicate the individual identification of the fish.
    - Recorders should mark off on the datasheet that tissue sample was collected.
    - In the event of fish that are tagged and later rejected, discard the tissue sample and envelope and use a marker to record the serial number of the new/alternate tag.
    - Once tagging is completed, during QA/QC, confirm number of envelopes. The coin envelopes will be presented to the tagging coordinator at the completion of each tagging session.
    - The coin envelopes will be returned to the FWS office daily, and should stay dry and be at room temperature. Putting envelopes into a sealed plastic bag should be avoided. Back at the office the tissues may be put into a dessicator and then mailed to NMFS.
  - Using a scalpel, make an incision approximately 5 mm in length beginning a few mm in front of the pelvic girdle. The incision should be just deep enough to penetrate the peritoneum, avoiding the internal organs. The spleen is generally near the incision point so pay close attention to the depth of the incision
  - Use forceps to open the incision to check that you did not damage any internal organs or cause excessive bleeding. If you observe damage or think you damaged an organ, do not implant the tag—reject that fish
  - One scalpel blade can be used on about 5–7 fish. If the scalpel is pulling rough or making jagged incisions, it needs to be changed prior to tagging the next fish
  - Remove a disinfected transmitter from the pill box

- Confirm the tube ID with the recorder and place the empty vial into the lid of the tray which holds the tags
- Gently insert the tag into the body cavity and position it so that it lies directly beneath the incision and the ceramic head is facing forward. This positioning will provide a barrier between the suture needle and internal organs
- Suture the incision with two to three interrupted stitches. Make note on the datasheet when three stitches are used, as two stiches is assumed to be the typical condition.
- Transfer the fish from the surgical platform to the appropriate recovery bucket with minimal handling by moving the platform as close as possible to the bucket or using a liner material to lift the fish for transfer
    - Immediately following surgery, fish will be held in recovery containers that provide 130–150% DO for a minimum of 10 min
    - Holding time in recovery containers begins when the last fish is added to the container and will be monitored using a timer
- Two recovery buckets are used for each group of three fish that will be transferred into one tote for transport to the release site. Call out the count of fish in the recovery buckets to the tagging assistant/recorder for confirmation. Put the lids back on the buckets. Once 3 fish are in the 2 buckets that make up a respective tote, attach the clipboard with tag datasheet to one of the two buckets and have the tagging assistant move the buckets to the tag verification staging area
- Between surgeries, the surgeon should replace the instruments that were just used into the disinfectant bath. Each surgeon will have at least 3 sets of surgical instruments to rotate through to ensure that tools get a thorough soaking in disinfectant between uses. Once disinfected, instruments should be rinsed in distilled or deionized water. Organic debris in the disinfectant bath reduces effectiveness, so be sure to change the bath regularly

*Transmitter Verification:*

- Obtain buckets and datasheet from tagging crew and start a timer for the 10 min surgical recovery period
- Gently place hydrophones attached to a VEMCO VR-100 into each bucket
- Watch the display on the VR-100 for tag codes that appear on the monitoring screen. As tag codes are verified circle the tag code that is read on the VR-100 on the copy of the Tag and Tote datasheet provided to the tag verifier
- Once all tags in a bucket have been verified, remove the hydrophone and secure the lid until the recovery period is complete
- Once the 10 min recovery period is complete, transfer the 2 buckets to an 18 gallon tote and confirm that all fish have recovered from anesthesia and are swimming normally.

Move the tote to the truck loading area. If tag codes are not verified after the 10 min recovery period, continue to attempt verification by separating fish to one per bucket.

- If a tag does not code out, notify the tag coordinator and return the fish to the surgeon who performed the surgery for tag extraction. Once the tag is removed, return to tag coordinator for a replacement tag to complete tag implantation
- Return the datasheet to the tagging crew

*Loading for Transport:*

- Begin completion of fish loading, transport, and release data sheets
- Fill transport tank with water at same temperature as source tank and make sure the flow through system is established before notifying the tag coordinator that tagging can commence
- Record temperature and DO in the transport tank
- Bring buckets to the truck and check each for general fish condition and dead fish before placing into the tank. If a dead fish is found, notify the tag coordinator and return the fish to the surgeon who performed the surgery for tag extraction. Once the tag is removed, return it to the tag coordinator so the tag code can be verified and a plan for reuse of the tag can be determined. The original entry should be crossed out in the data sheet with the comment "Mort at loading"
- Call out the number of the bucket to the recorder and the number of fish in the bucket
- Once all buckets have been loaded, confirm that the number of buckets matches the number that should be loaded and that there are no buckets remaining in the tagging area
- Secure the tank and tank lid for transport
- Send previous day's datasheets with transport crew (first transport truck)

*End of session activities:*

- Validation of tag data and datasheet accuracy
    - Working together, each surgeon and assistant team will review the transmitter tubes/serial numbers against the tag and tote inventory and the datasheets to verify that all of the transmitters provided for the session were implanted into study fish
    - The steps of the verification process should include reading the serial number on each tag tube, finding that serial number on the datasheet to confirm that it was implanted, and a simple count of the tags provided (as shown on the tag-tote inventory) vs. the tag tubes and data rows on the datasheets
    - Once the validation steps have been completed, both the surgeon and the assistant initial the datasheet to confirm that the validation step has been completed
- Validation of genetic sample accuracy

- Following a similar process to what was done for tag data, the surgeon and assistant should work together to confirm that they have a complete and accurate collection of coin envelopes containing genetic samples
    - The steps of the verification process should include reading the serial number on each envelope and comparing it to the tags listed on the tag and tote inventory to ensure that all appropriate genetic samples were collected
    - Once the validation steps have been completed, both the surgeon and the assistant initial the datasheet to confirm that this validation step has been completed
- Review all datasheets and complete any missing information (e.g., tag end time, page numbers, validation initials)
- Collect all datasheets, pill boxes, coin envelopes, and tag tubes and hand them in to the tagging coordinator
- Organize tagging solutions and surgical instruments to be ready for the next tagging session

*End of day clean up:*

- At the end of each tagging day, wipe down or spray all surfaces with Virkon or 70% EtOH to disinfect
- Use a toothbrush to remove all large organic debris from instruments, rinse them, and dry them to prevent rust
- Return all surgical instruments to the office for autoclaving
- Make surgical tagging solutions as needed to be ready for the next tagging session
- Inventory chemical solutions and tagging supplies (blades and sutures)
- Return any soiled rags to the office and have them washed
- Rinse buckets with hose and place upside down to dry
- Turn off oxygen cylinder

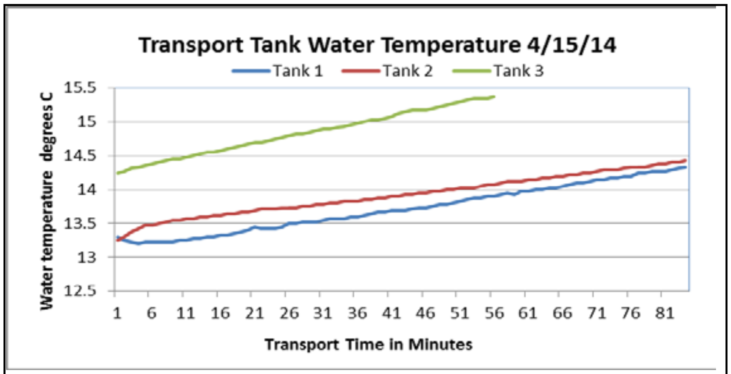
***General Fish Handling Reminders:***

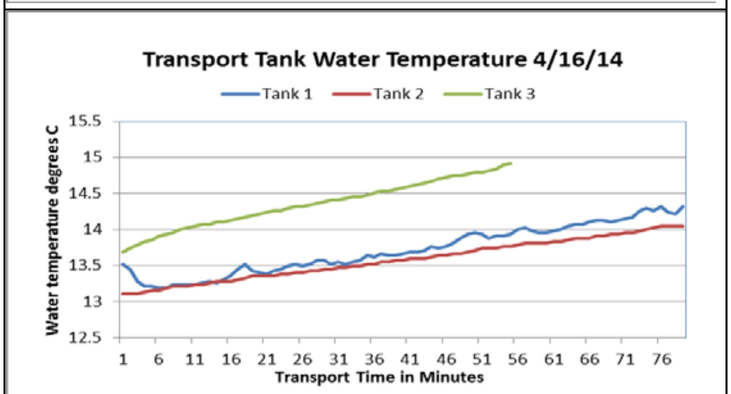
- Anesthesia and freshwater carboys and buckets should be filled just prior to tagging to avoid temperature changes and should be changed often. Check levels of carboys before each surgery to be certain that you will not run out of water during a surgery
- **USE CAUTION and COMMUNICATION** when adding Aqui-S 20E to any container to avoid adding two doses or no doses to the container
- Keep a lid on any bucket or tote that contains fish
- Any fish dropped on the floor should be rejected. If a fish is dropped on the floor after it has been tagged, euthanize the fish, remove the tag, disinfect the tag, and place it into another fish
- **CAREFULLY HANDLE BUCKETS**. Try not to bang them around, slam the handles, or otherwise handle in a rough manner as this can stress fish

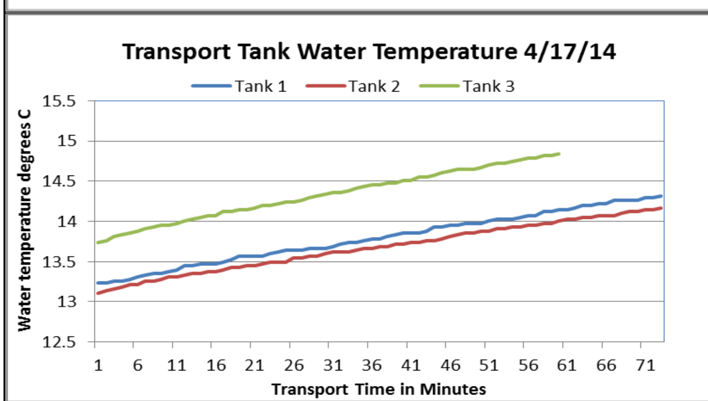
- **USE A SANCTUARY NET** to capture source fish and place them into an anesthesia bucket. A recommended approach is to use a non-sanctuary net in the container of source fish in order to be able to capture the fish without them detecting the pressure wave in front of the sanctuary net. Once a fish is in the traditional net, place the sanctuary net immediately below the fish so that the handles of the two nets are aligned and can be handled together.

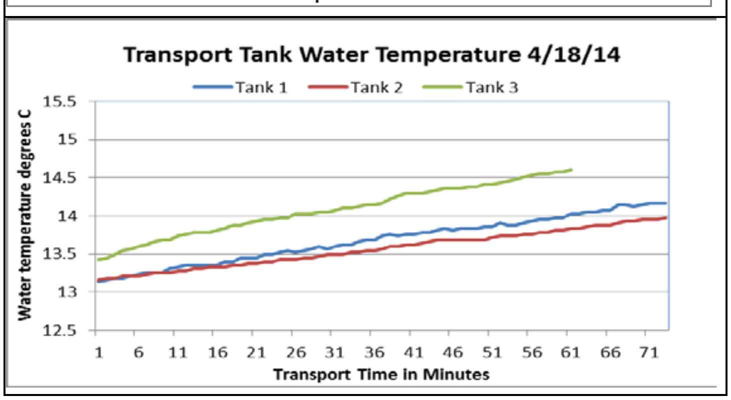
## Appendix C

## Water temperature recorded in transport tanks (1, 2 and 3) during each daily transport

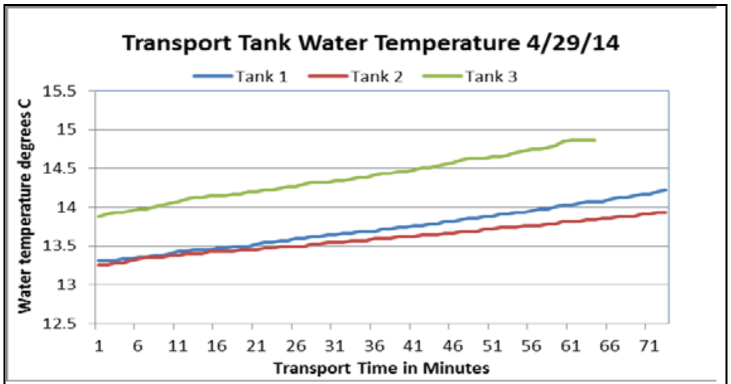


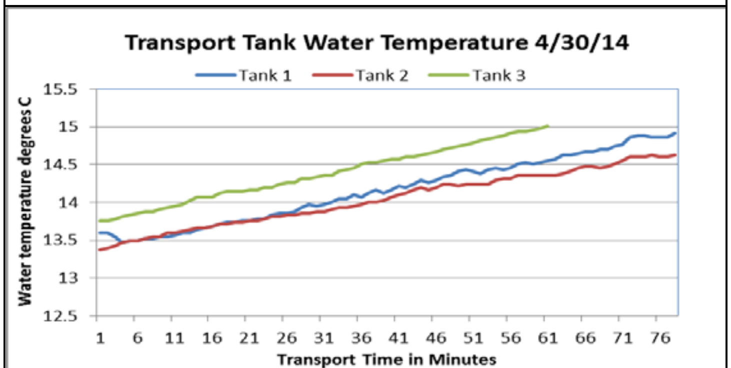



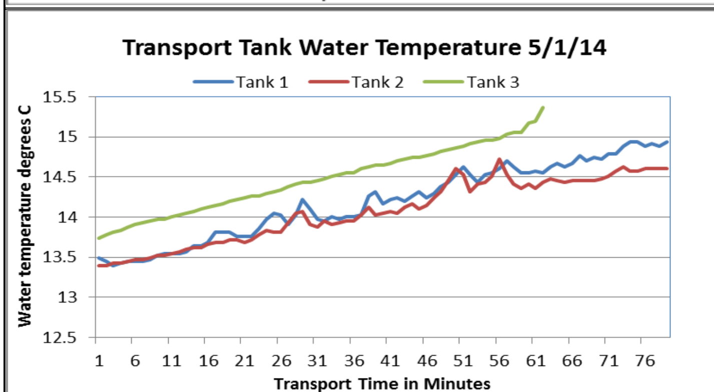



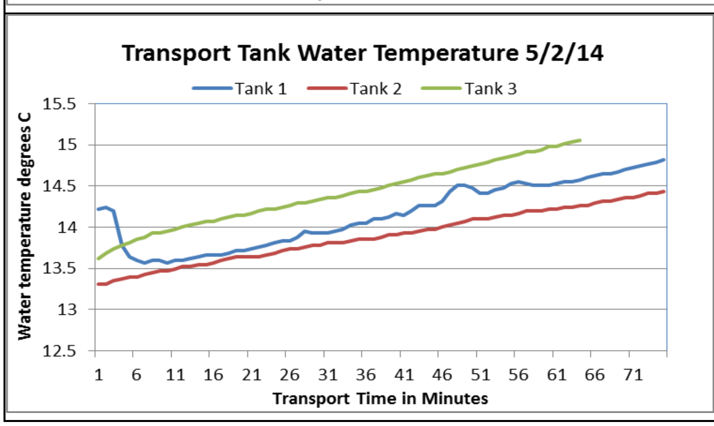



## Appendix C (continued)

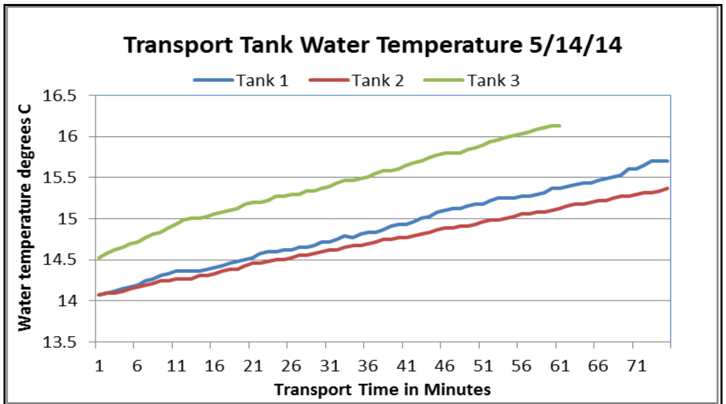


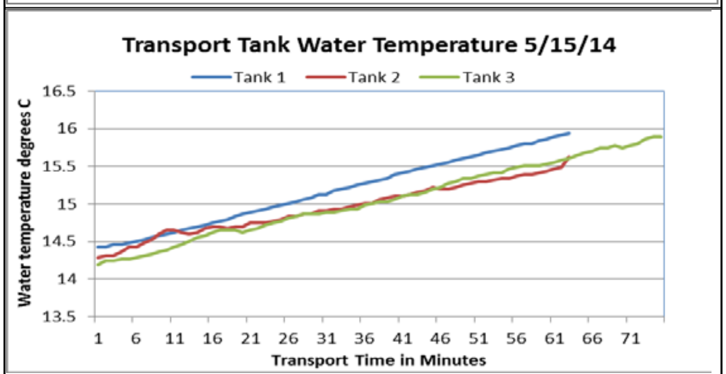



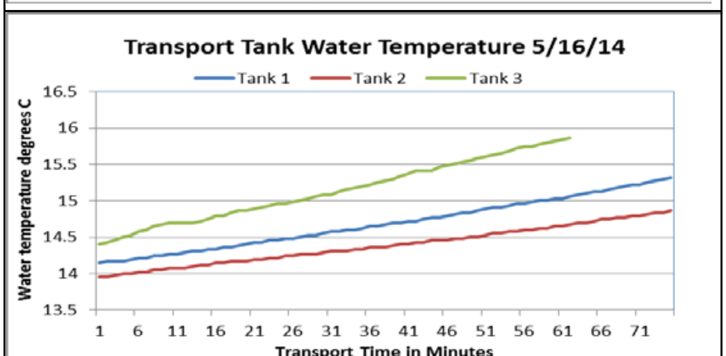



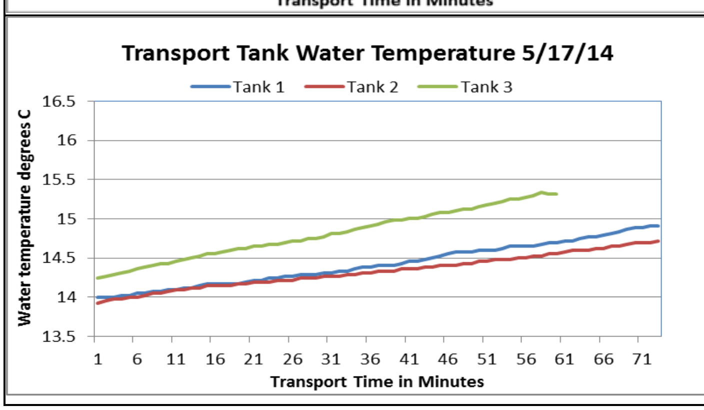



## Appendix C (continued)



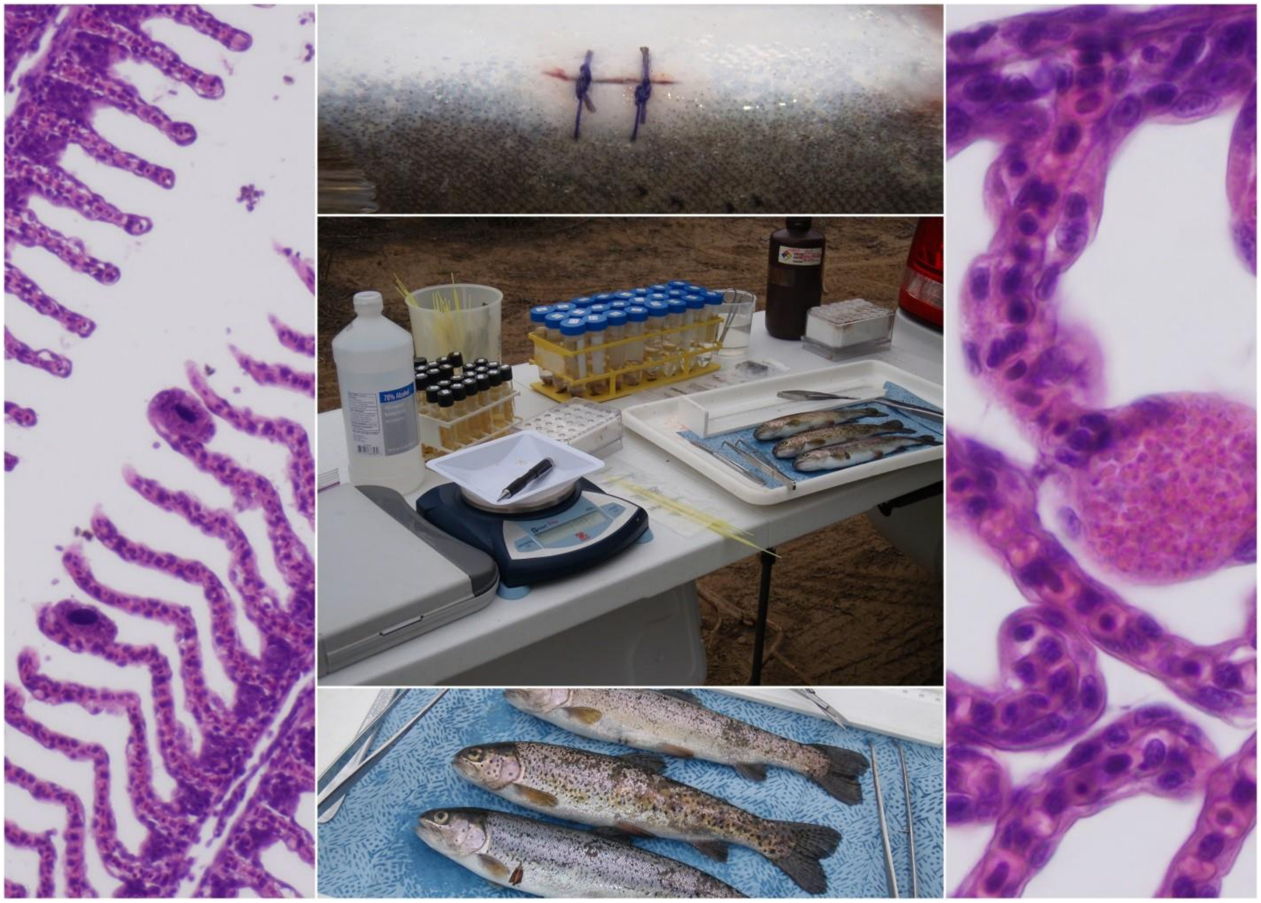



Appendix D:

# Pathogen Screening and Gill $Na^+/K^+$- ATPase Assessment of South Delta Chinook and Steelhead 2014 Release Groups

Ken Nichols



September 2014

US Fish and Wildlife Service
California-Nevada Fish Health Center
24411 Coleman Fish Hatchery Rd
Anderson, CA 96007
(530) 365-4271 Fax: (530) 365-7150
http://www.fws.gov/canvfhc/

## Summary

The health and physiological condition of the study fish can help explain their performance and survival during the studies. Juvenile Chinook salmon and steelhead trout were surveyed for specific fish pathogens and smolt development using gill $Na^{+}/K^{+}$-ATPase (gill ATPase) activity levels. In both steelhead and Chinook release groups, survival over the 24 holding period was high. No significant pathogen infections were detected in Chinook or steelhead release groups. Gill ATPase levels were stable or increasing over the study period suggesting levels of smolt development would not be a factor in fish performance.

Recommended citation for this report is:

Nichols, K. 2014. Pathogen Screening and Gill Na+/K+- ATPase Assessment of South Delta Chinook and Steelhead 2014 Release Groups. U.S. Fish & Wildlife Service, California-Nevada Fish Health Center, Anderson, CA. Available: http://www.fws.gov/canvfhc/reports.asp.

## Background

As a component of studies examining the reach-specific survival and distribution of migrating juvenile Chinook salmon and steelhead in the San Joaquin River and Delta, the CA-NV Fish Health Center conducted a general pathogen screening and smolt physiological assessment. Steelhead trout were examined in support of the 6-year Study required by the 2009 Biological Opinion on Central Valley Project and State Water Project operations (RPA IV.2.2). The health and physiological condition of the study fish can help explain their performance and survival during the studies. Similar pathogen screening and physiological assessments have been conducted on Chinook used in various south delta studies since 1996. Juvenile Chinook from Merced River Hatchery used in the majority of these past examinations had varying levels of infections with the myxozoan parasite *Tetracapsuloides bryosalmonae*, the causative agent of Proliferative Kidney Disease (PKD). In 2014, severe PKD in Merced River Chinook required a shift to juvenile Chinook from Mokelumne River Fish Hatchery.

## Methods

### *Fish Sampling*

All study fish were cohorts of acoustic-tagged release groups and shadowed each release group through handling, tagging (dummy-tagged), transport, and in-river holding. Study fish were held for 48 hours at the Durham Ferry release site on the San Joaquin River before sampling. Groups of 30 juvenile Mokelumne River Hatchery Chinook salmon were sampled on 19 April, 4 May and 19 May, 2014. Groups of 24 Mokelumne River Hatchery yearling steelhead trout were sampled on 29 March, 27 April and 24 May, 2014. Fish were euthanized, fork length (FL) was recorded, any abnormalities were noted and tissue sampled for lab assays.

### *Lab Assays*

Bacteriology – A sample of kidney tissue was collected aseptically and inoculated onto brain-heart infusion agar. Bacterial isolates were screened by standard microscopic and biochemical tests (USFWS and AFS-FHS 2010). These screening methods would not detect *Flavobacterium columnare*. *Renibacterium salmoninarum* (the bacteria that causes bacterial kidney disease) was screened by fluorescent antibody test of kidney imprints.

Virology – Three fish pooled samples of kidney and spleen were inoculated onto EPC and CHSE-214 at 15°C as described in the AFS Bluebook (USFWS and AFS-FHS 2010) with the exception that no blind pass was performed.

Histopathology – The tissues were removed from the fish and immediately fixed in Davidson's fixative. In the lab, the tissues were processed for 5 µm paraffin sections and stained with hematoxylin and eosin (Humason 1979). All tissues for a given fish were placed on one slide and identified by a unique code number. Each slide was examined under a light microscope and observations of abnormalities were noted. In steelhead release groups, gill tissues from all 24 fish were examined for signs of external parasite infection. In Chinook release groups, gill, kidney, liver and intestine tissues from 10 fish per group were examined for parasite infection or other abnormalities.

Gill ATPase – Gill $Na^+/K^+$-Adenosine Triphosphatase (gill ATPase) activity was assayed by the method of McCormick (1993). Gill ATPase activity is correlated with osmoregulatory ability in saltwater, and high concentrations are found in the chloride cells of the lamellae.

## Results

### *Fish condition*

Chinook – Prior to the health assessment, one fish died in 19 April group and no mortality occurred in the 4 May or 19 May release groups (Table D1). A penetrating abdominal wound (external abnormality) and degenerated intestine (internal abnormality) were noted on this single mortality. No significant scale loss or pale gills were noted in any of the Chinook health sample groups. Overall, sutures from tagging surgery were in good conditions with minor inflammation noted in 3% (1/30) of fish sampled 19 April; a loose suture noted in 3% of (1/30) fish sampled 4 May; and minor hemorrhaging noted in 13% (4/30) of fish sampled 19 May.

**Table D1. Chinook release group mean (± sd) fork length (FL), mortality over the 48 hr. holding period, fish with external abnormalities (Ext Abn), fish with internal abnormalities (Int Abn) and number of fish sampled for lab assays (N).**

| Group | FL (mm) | Mortality | Ext Abn | Int Abn | N |
|---|---|---|---|---|---|
| 19 April | 96.2 ±5.1 | 1/30 (3%) | 0/30 (0%) | 0/30 (0%) | 29 |
| 4 May | 101.2 ±4.4 | 0/30 (0%) | 0/30 (0%) | 0/30 (3%) | 30 |
| 19 May | 99.5 ±5.2 | 0/30 (0%) | 0/30 (0%) | 0/30 (3%) | 30 |

Steelhead – One fish died prior to the health assessment in the 29 March release group, and no mortality occurred in the 27 April or 24 May groups (Table D2). No wounds or clinical signs of infection were observed on the single mortality. In the 29 March health assessment group, no significant external or internal abnormalities were noted, and minor hemorrhaging or inflammation (Figure D1) at the suture site was observed in 21% (5/24) of fish. In the 27 April health assessment group, cloudy eyes were noted in 4% (1/24) of fish, and partly open or bleeding sutures were observed in 8% (2/24) of fish. In the 24 May group, significant scale loss (>50% of body) was noted in 13% (3/24) of fish; 4% (1/24) of fish had eye abnormalities; and minor hemorrhaging or partly open sutures were noted in 21% (5/24) of fish.

**Table D2. Steelhead release group mean (± sd) fork length (FL), mortality over the 48 hr. holding period, fish with external abnormalities (Ext Abn), fish with internal abnormalities (Int Abn), and number of fish sampled for lab assays (N).**

| Group | FL (mm) | Mortality | Ext Abn | Int Abn | N |
|---|---|---|---|---|---|
| 29 March | 240 (±14) | 1/24 (4%) | 0/24 (0%) | 0/24 (0%) | 23 |
| 27 April | 250 (±13) | 0/24 (0%) | 1/24 (4%) | 0/24 (0%) | 24 |
| 24 May | 249 (±17) | 0/24 (0%) | 4/24 (17%) | 0/24 (0%) | 24 |

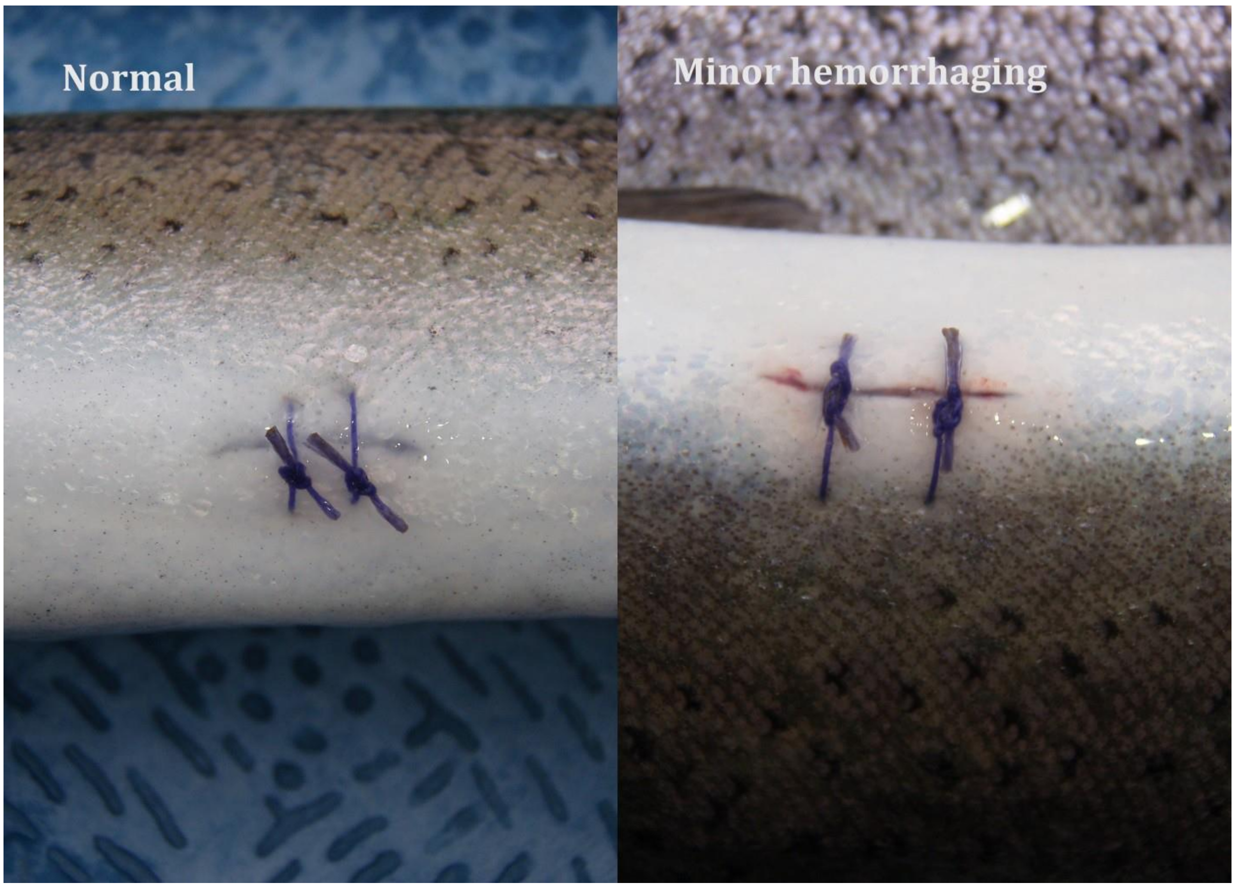



**Figure D1. Examples of normal sutures and minor hemorrhaging at suture site in fish assessed after holding for 48 hours.**

### *Bacteriology and virology*

In both Chinook and steelhead sample groups, no virus or other cytopathic effects were observed by cell culture over the 21 day incubation period. No obligate bacterial pathogens were detected, and other isolates were isolated in 3-24% of sample groups (Table D3). These other isolates were common fauna in the environment and fishes GI tract (Aoki 1999) and were likely contaminates due to field sampling conditions.

**Table D3. Summary of bacteria isolated from the kidneys of dummy-tagged fish.**

| Species | *Aeromonas* /*Pseudomonas* | various Gram positive bacteria |
|---|---|---|
| Chinook | 3% (3/87) | 17% (15/87) |
| Steelhead | 11% (8/71) | 24% (17/71) |

### *Histopathology*

Chinook – No significant abnormalities or signs of infection were detected in tissues from the 30 fish examined.

Steelhead – No significant abnormalities were observed on the gills of 69 fish examined; however, subclinical parasite infections were observed. Light infections with *Capriniana piscium* (Figure D2A, formerly known as *Trichophrya*, presumptive identification) were observed in 75% (52/69) of gills. Cyst-like xenoma (Figure D2B) caused by an unidentified microsporidian were observed in 3% (2/69) of gill samples. There was no associated lesion or other sign of impairment associated with these infections.

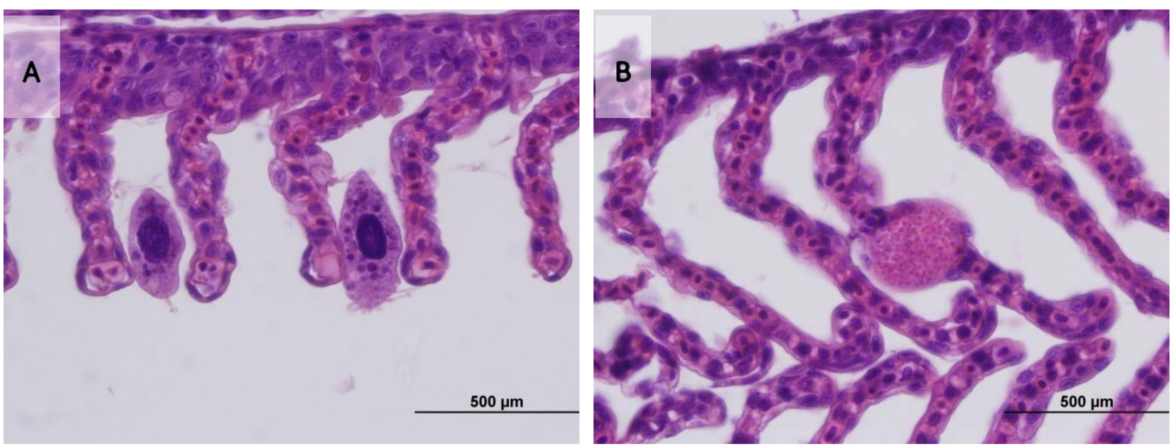



**Figure D2. Histology sections (H&E stained) of steelhead gills with (A) *Capriniana piscium* (formerly *Trichophrya*) infections, and (B) Cyst-like xenoma. Note the absence of significant inflammation or lesion in both infections.**

### *Gill ATPase activity*

Chinook Salmon – Gill ATPase activity levels (µmol ADP*mg protein$^{-1}$*h$^{-1}$) ranged from 0.6 to 14.3. Two fish from the 19 April sample group were excluded from the analysis due to extremely high activity levels, which were likely errors in the protein measurement. The activity levels in the 4 May release group were lower than the 19 April and 19 May groups (Figure D3, P < 0.001, ANOVA).

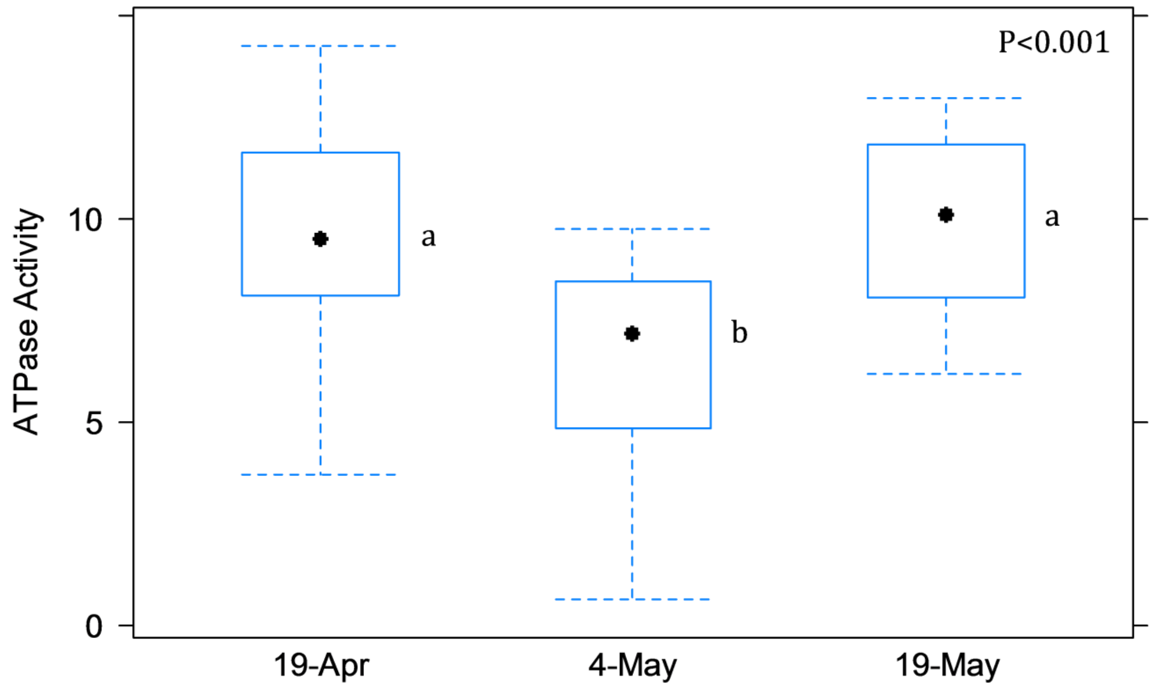



**Figure D3. Boxplot of median gill ATPase activity (µmol ADP·mg protein$^{-1}$·hr$^{-1}$) in juvenile Chinook salmon sampled from the 19 April, 4 May and 19 May release groups. Groups with letter subscripts in common were not significantly different (P<0.001, ANOVA).**

Steelhead – Gill ATPase activity levels (µmol ADP*mg protein$^{-1}$*hr$^{-1}$) ranged from 0.2 to 5.7. Activity levels tended to increase with the highest levels observed in the May release group (Figure D4, P = 0.008, ANOVA).

## Discussion

No significant health issues were observed in either the Chinook or steelhead release groups in 2014. The Chinook salmon from Mokelumne River Hatchery used in the study this year did not have any signs of *T. bryosalmonae* infections common in the Merced River Hatchery Chinook during past years. The minor suture issues observed in both Chinook and steelhead release groups were observed in only a few individuals and did not impact overall health of the fish. Several steelhead from the 24 May release group were observed to have significant scale loss which may have been an indication of higher smolt development.

Gill ATPase activity levels were stable or increasing over the study period suggesting smolt development would not be a significant factor in fish performance. Gill ATPase activity in salmonids typically increases and peaks near the time of most active migratory behavior (Duston, Saunders and Knox 1991; Ewing, Ewing and Satterthwaite

2001; Wedemeyer 1996). In Chinook sample groups, gill ATPase levels were similar in the first (19 April) and last (19 May) release groups suggesting these fish were not yet past time peak smolt development. The cause of the lower median gill ATPase levels observed in the second (4 May) Chinook release group was not apparent. While in steelhead sample groups, gill ATPase levels increased over time the relationship with migration behavior may not be consistent. In unpublished CA-NV Fish Health Center data, steelhead have demonstrated the ability to significantly increase activity levels in only a few days following hatchery release.

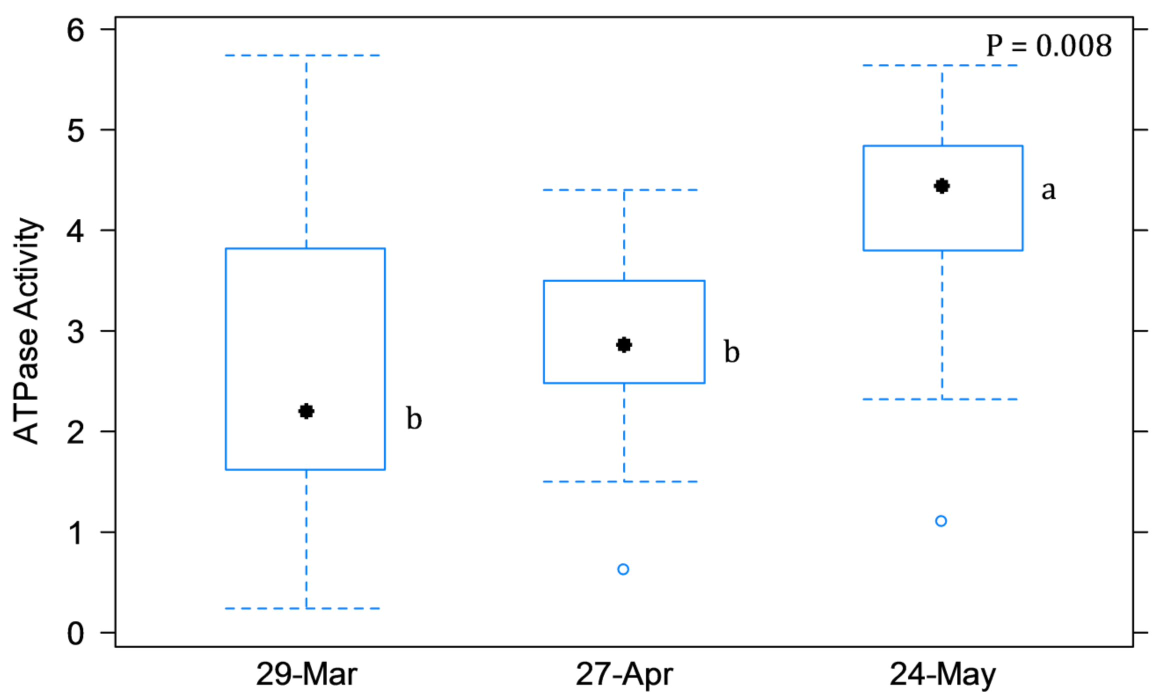



**Figure D4. Boxplot of median gill ATPase activity (µmol ADP·mg protein$^{-1}$·h$^{-1}$) in juvenile steelhead from the March, April, and May release groups. Groups with letter subscripts in common were not significantly different (P = 0.008, ANOVA).**

## Acknowledgments


Biologists with the USFWS Stockton FWO provided help with logistics and fish handling. Scott Foott with the CA-NV Fish Health Center provided valuable assistance with field sampling and laboratory assays.

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## Appendix E
## Survival Model Parameters

**Table E1. Definitions of parameters used in the release-recapture survival model. Parameters used only in the full model (Submodel I or Submodel II) but not in the implemented models are noted.**

| Parameter | Definition |
|---|---|
| $S_{A2}$ | Probability of survival from Durham Ferry Downstream (DFD) to Banta Carbona (BCA) |
| $S_{A3}$ | Probability of survival from Banta Carbona (BCA) to Mossdale (MOS) |
| $S_{A4}$ | Probability of survival from Mossdale (MOS) to Lathrop (SJL) or Old River East (ORE) |
| $S_{A5}$ | Probability of survival from Lathrop (SJL) to Garwood Bridge (SJG) |
| $S_{A6}$ | Probability of survival from Garwood Bridge (SJG) to Navy Drive Bridge (SJNB) or Burns Cutoff (RRI) receivers |
| $S_{A6,G2}$ | Overall survival from Garwood Bridge (SJG) to Chipps Island (MAE/MAW) |
| $S_{A7}$ | Probability of survival from Navy Drive Bridge (SJNB) to MacDonald Island (MAC) or Turner Cut (TCE/TCW) |
| $S_{A7,G2}$ | Overall survival from Navy Drive Bridge (SJNB) to Chipps Island (MAE/MAW) |
| $S_{R1}$ | Probability of survival from Burns Cutoff (RRI) to MacDonald Island (MAC) or Turner Cut (TCE/TCW) |
| $S_{R1,G2}$ | Overall survival from Burns Cutoff (RRI) to Chipps Island (MAE/MAW) |
| $S_{B1}$ | Probability of survival from Old River East (ORE) to Old River South (ORS) or Middle River head (MRH); full model only |
| $S_{B2,G2}$ | Overall survival from Old River South (ORS) to Chipps Island (MAE/MAW) |
| $\phi_{A1,A0}$ | Joint probability of moving from Durham Ferry release site upstream toward DFU, and surviving to DFU |
| $\phi_{A1,A2}$ | Joint probability of moving from Durham Ferry release site downstream toward DFD, and surviving to DFD |
| $\phi_{B1,B2}$ | Joint probability of moving from ORE toward ORS, and surviving from ORE to ORS; = $S_{B1}\psi_{B2}$ |
| $\phi_{B2,B4}$ | Joint probability of moving from ORS toward OR4, and surviving from ORS to OR4 |
| $\phi_{B2,C2}$ | Joint probability of moving from ORS toward MR4, and surviving from ORS to MR4 |
| $\phi_{B2,D1}$ | Joint probability of moving from ORS toward RGU, and surviving from ORS to RGU |
| $\phi_{B2,E1}$ | Joint probability of moving from ORS toward CVP, and surviving from ORS to CVP |
| $\phi_{B4,G2}$ | Joint probability of moving from OR4 toward Chipps Island (MAE/MAW), and surviving from OR4 to MAE/MAW; full model only |
| $\phi_{C1,B4}$ | Joint probability of moving from MRH toward OR4, and surviving from MRH to OR4 |
| $\phi_{C1,C2}$ | Joint probability of moving from MRH toward MR4, and surviving from MRH to MR4 |
| $\phi_{C1,D1}$ | Joint probability of moving from MRH toward RGU, and surviving from MRH to RGU |
| $\phi_{C1,E1}$ | Joint probability of moving from MRH toward CVP, and surviving from MRH to CVP |
| $\phi_{C2,G2}$ | Joint probability of moving from MR4 toward Chipps Island (MAE/MAW), and surviving from MR4 to MAE/MAW; full model only |
| $\phi_{D1,D2}$ | Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD; full model only |
| $\phi_{D2,G2}$ | Joint probability of moving from RGD toward Chipps Island (MAE/MAW) and surviving from RGU to MAE/MAW; full model only |
| $\phi_{E1,E2}$ | Joint probability of moving from CVP toward CVPtank, and surviving from CVP to CVPtank; full model only |
| $\phi_{E2,G2}$ | Joint probability of moving from CVPtank toward Chipps Island (MAE/MAW) and surviving from CVPtank to MAE/MAW; full model only |
| $\psi_{A1}$ | Probability of remaining in the San Joaquin River at the head of Old River; = 1 - $\psi_{B1}$ |
| $\psi_{A2}$ | Probability of remaining in the San Joaquin River at Burns Cutoff; 1 - $\psi_{R2}$ |
| $\psi_{A3}$ | Probability of remaining in the San Joaquin River at Turner Cut; 1 - $\psi_{F3}$ |
| $\psi_{B1}$ | Probability of entering Old River at the head of Old River; = 1 - $\psi_{A1}$ |
| $\psi_{B2}$ | Probability of remaining in Old River at the head of Middle River; = 1 - $\psi_{C2}$; full model only |

Table E1. (Continued)

| Parameter | Definition |
|---|---|
| $\psi_{C2}$ | Probability of entering Middle River at the head of Middle River; = 1 - $\psi_{B2}$; full model only |
| $\psi_{R2}$ | Probability of entering Burns Cutoff at its upstream junction with the San Joaquin River; = 1 - $\psi_{A2}$ |
| $\psi_{F3}$ | Probability of entering Turner Cut at its junction with the San Joaquin River; = 1 - $\psi_{A3}$ |
| $P_{A0a}$ | Conditional probability of detection at DFU1 |
| $P_{A0b}$ | Conditional probability of detection at DFU2 |
| $P_{A0}$ | Conditional probability of detection at DFU (either DFU1 or DFU2) |
| $P_{A2}$ | Conditional probability of detection at DFD (either DFD1 or DFD2) |
| $P_{A3}$ | Conditional probability of detection at BCA |
| $P_{A4}$ | Conditional probability of detection at MOS |
| $P_{A5a}$ | Conditional probability of detection at SJLU |
| $P_{A5b}$ | Conditional probability of detection at SJLD |
| $P_{A5}$ | Conditional probability of detection at SJL (either SJLU or SJLD) |
| $P_{A6a}$ | Conditional probability of detection at SJGU |
| $P_{A6b}$ | Conditional probability of detection at SJGD |
| $P_{A6}$ | Conditional probability of detection at SJG (either SJGU or SJGD) |
| $P_{A7a}$ | Conditional probability of detection at SJNBU |
| $P_{A7b}$ | Conditional probability of detection at SJNBD |
| $P_{A7}$ | Conditional probability of detection at SJNB (either SJNBU or SJNBD) |
| $P_{A8a}$ | Conditional probability of detection at MACU |
| $P_{A8b}$ | Conditional probability of detection at MACD |
| $P_{A8}$ | Conditional probability of detection at MAC (either MACU or MACD) |
| $P_{A9a}$ | Conditional probability of detection at MFE; full model only |
| $P_{A9b}$ | Conditional probability of detection at MFW; full model only |
| $P_{A9}$ | Conditional probability of detection at MFE/MFW (either MFE or MFW); full model only |
| $P_{B1a}$ | Conditional probability of detection at OREU |
| $P_{B1b}$ | Conditional probability of detection at ORED |
| $P_{B1}$ | Conditional probability of detection at ORE (either OREU or ORED) |
| $P_{B2a}$ | Conditional probability of detection at ORSU |
| $P_{B2b}$ | Conditional probability of detection at ORSD |
| $P_{B2}$ | Conditional probability of detection at ORS (either ORSU or ORSD) |
| $P_{B4a}$ | Conditional probability of detection at OR4U |
| $P_{B4b}$ | Conditional probability of detection at OR4D |
| $P_{B4}$ | Conditional probability of detection at OR4 (either OR4U or OR4D) |
| $P_{C1a}$ | Conditional probability of detection at MRHU |
| $P_{C1b}$ | Conditional probability of detection at MRHD |
| $P_{C1}$ | Conditional probability of detection at MRH (either MRHU or MRHD) |
| $P_{C2a}$ | Conditional probability of detection at MR4U |
| $P_{C2b}$ | Conditional probability of detection at MR4D |
| $P_{C2}$ | Conditional probability of detection at MR4 (either MR4U or MR4D) |

**Table E1. (Continued)**

| Parameter | Definition |
|---|---|
| $P_{D1}$ | Conditional probability of detection at RGU (either RGU1 or RGU2) |
| $P_{D2a}$ | Conditional probability of detection at RGD1; full model only |
| $P_{D2b}$ | Conditional probability of detection at RGD2; full model only |
| $P_{D2}$ | Conditional probability of detection at RGD (either RGD1 or RGD2); full model only |
| $P_{E1}$ | Conditional probability of detection at CVP (either CVPU or CVPD) |
| $P_{E2}$ | Conditional probability of detection at CVPtank; full model only |
| $P_{F1a}$ | Conditional probability of detection at TCE |
| $P_{F1b}$ | Conditional probability of detection at TCW |
| $P_{F1}$ | Conditional probability of detection at TCE/TCW (either TCE or TCW) |
| $P_{R1a}$ | Conditional probability of detection at RRIU |
| $P_{R1b}$ | Conditional probability of detection at RRID |
| $P_{R1}$ | Conditional probability of detection at RRI (either RRIU or RRID) |
| $P_{G2a}$ | Conditional probability of detection at MAE |
| $P_{G2b}$ | Conditional probability of detection at MAW |
| $P_{G2}$ | Conditional probability of detection at MAE/MAW |
| $\lambda$ | Joint probability of surviving from Chipps Island to Benicia Bridge and detection at Benicia Bridge |
| $\lambda_{A4}$ | Joint probability of surviving from MOS to Benicia Bridge and detection at Benicia Bridge; = $S_{Total}\lambda$ |
| $\lambda_{A6}$ | Joint probability of surviving from SJG to Benicia Bridge and detection at Benicia Bridge; = $S_{A6,G2}\lambda$ |
| $\lambda_{A7}$ | Joint probability of surviving from SJNB to Benicia Bridge and detection at Benicia Bridge; = $S_{A7,G2}\lambda$ |
| $\lambda_{B1}$ | Joint probability of surviving from ORE to Benicia Bridge and detection at Benicia Bridge; = $\phi_{B1,B2},S_{B2,G2}\lambda$ |
| $\lambda_{B2}$ | Joint probability of surviving from ORS to Benicia Bridge and detection at Benicia Bridge; = $S_{B2,G2}\lambda$ |
| $\lambda_{R1}$ | Joint probability of surviving from RRI to Benicia Bridge and detection at Benicia Bridge; = $S_{R1,G2}\lambda$ |
| $\lambda_D$ | Joint probability of surviving from RGU to RGD, and detection at RGD; = $\phi_{D1,D2}P_{D2}$ |
| $\lambda_E$ | Joint probability of surviving from E1 to E2, and detection at E2; = $\phi_{E1,E2}P_{E2}$ |

**Table E2. Parameter estimates (standard errors in parentheses) from survival model for tagged juvenile Chinook Salmon released in 2014, excluding predator-type detections. Parameters without standard errors were estimated at fixed values in the model. Population-level estimates are from pooled data from release groups 2 and 3. Some parameters were not estimable because of sparse data. Estimates for release group 1 were not adjusted for premature tag failure.**

| Parameter | 1 | 2 | 3 | Population Estimate (Releases 2 and 3) |
|---|---|---|---|---|
| $S_{A2}$ | 0.97 (0.13) | 0.68 (0.13) | 0.20 (0.03) | 0.34 (0.04) |
| $S_{A3}$ | 0.49 (0.05) | 0.42 (0.07) | 0.37 (0.05) | 0.52 (0.04) |
| $S_{A4}$ | 0.64 (0.03) | 0.47 (0.04) | 0.78 (0.06) | 0.53 (0.03) |
| $S_{A5}$ | 0.24 (0.03) | 0.20 (0.05) | 0.10 (0.05) | 0.17 (0.04) |
| $S_{A6}$ | 0.73 (0.07) | 0.80 (0.10) | | 0.72 (0.10) |
| $S_{A6,G2}$ | 0 | | | |
| $S_{A7}$[a] | 0.13 (0.05) | 0.13 (0.05) | 0.13 (0.05) | 0.13 (0.05) |
| $S_{A7,G2}$ | 0 | | | |
| $S_{R1}$[a] | 0 | 0 | 0 | 0 |
| $S_{R1,G2}$ | 0 | | | |
| $S_{B1}$ | | | | |
| $S_{B2,G2}$ | 0.11 (0.10) | | | |
| $\phi_{A1,A0}$ | | | 0.04 (0.01) | 0.02 (<0.01) |
| $\phi_{A1,A2}$ | 0.93 (0.10) | 0.93 (0.10) | 0.90 (0.09) | 0.92 (0.06) |
| $\phi_{B1,B2}$ | 0.53 (0.12) | 0.57 (0.19) | | 0.67 (0.16) |
| $\phi_{B2,B4}$ | | | | |
| $\phi_{B2,C2}$ | | | | |
| $\phi_{B2,D1}$[a] | 0.07 (0.06) | 0.07 (0.06) | 0.07 (0.06) | 0.07 (0.06) |
| $\phi_{B2,E1}$[a] | 0.27 (0.11) | 0.27 (0.11) | 0.27 (0.11) | 0.27 (0.11) |
| $\phi_{B4,G2}$ | | | | |
| $\phi_{C1,B4}$ | | | | |
| $\phi_{C1,C2}$ | | | | |
| $\phi_{C1,D1}$ | | | | |
| $\phi_{C1,E1}$ | | | | |
| $\phi_{C2,G2}$ | | | | |
| $\phi_{D1,D2}$ | | | | |
| $\phi_{D2,G2}$ | | | | |
| $\phi_{E1,E2}$ | | | | |
| $\phi_{E2,G2}$ | | | | |
| $\psi_{A1}$ | 0.91 (0.02) | 0.91 (0.03) | 0.94 (0.04) | 0.92 (0.02) |
| $\psi_{A2}$ | 0.93 (0.04) | 0.75 (0.12) | | 0.77 (0.12) |
| $\psi_{A3}$[a] | 0.60 (0.22) | 0.60 (0.22) | 0.60 (0.22) | 0.60 (0.22) |
| $\psi_{B1}$ | 0.09 (0.02) | 0.09 (0.03) | 0.06 (0.04) | 0.08 (0.02) |
| $\psi_{B2}$ | | | | |
| $\psi_{C2}$ | | | | |
| $\psi_{R2}$ | 0.07 (0.04) | 0.25 (0.12) | | 0.23 (0.12) |
| $\psi_{F3}$[a] | 0.40 (0.22) | 0.40 (0.22) | 0.40 (0.22) | 0.40 (0.22) |

a = Parameters were equated across all three release groups in last reaches of SD model (affects marked parameters)

b = unique parameters were estimated for different release groups; no pooled estimate is available.

Table E2. (Continued)

| Parameter | 1 | 2 | 3 | Population Estimate (Releases 2 and 3) |
|---|---|---|---|---|
| $P_{A0a}$ | | | 0.70 (0.14) | 0.70 (0.14) |
| $P_{A0b}$ | | | 0.41 (0.12) | 0.41 (0.12) |
| $P_{A0}$ | | | 0.82 (0.10) | 0.82 (0.10) |
| $P_{A2}$ | 0.11 (0.02) | 0.21 (0.03) | 0.48 (0.05) | NA[b] |
| $P_{A3}$ | 0.18 (0.02) | 0.14 (0.03) | 0.78 (0.06) | NA[b] |
| $P_{A4}$ | 0.99 (<0.01) | 1 | 1 | 1 |
| $P_{A5a}$ | | 0.90 (0.04) | 0.97 (0.03) | 0.92 (0.03) |
| $P_{A5b}$ | | 0.94 (0.03) | 1 | 0.96 (0.02) |
| $P_{A5}$ | 1 | 0.99 (<0.01) | 1 | 1.00 (<0.01) |
| $P_{A6a}$ | | 1 | 1 | 1 |
| $P_{A6b}$ | | 1 | 1 | 1 |
| $P_{A6}$ | 1 | 1 | 1 | 1 |
| $P_{A7a}$ | 1 | 1 | | 1 |
| $P_{A7b}$ | 1 | 1 | | 1 |
| $P_{A7}$ | 1 | 1 | | 1 |
| $P_{A8a}$[a] | 1 | 1 | 1 | 1 |
| $P_{A8b}$[a] | 1 | 1 | 1 | 1 |
| $P_{A8}$[a] | 1 | 1 | 1 | 1 |
| $P_{A9a}$ | | | | |
| $P_{A9b}$ | | | | |
| $P_{A9}$ | | | | |
| $P_{B1a}$ | 1 | 1 | 1 | 1 |
| $P_{B1b}$ | 1 | 1 | 1 | 1 |
| $P_{B1}$ | 1 | 1 | 1 | 1 |
| $P_{B2a}$ | 1 | 1 | | 1 |
| $P_{B2b}$ | 1 | 1 | | 1 |
| $P_{B2}$ | 1 | 1 | | 1 |
| $P_{B4a}$ | | | | |
| $P_{B4b}$ | | | | |
| $P_{B4}$ | | | | |
| $P_{C1a}$ | | | | |
| $P_{C1b}$ | | | | |
| $P_{C1}$ | | | | |
| $P_{C2a}$ | | | | |
| $P_{C2b}$ | | | | |
| $P_{C2}$ | | | | |
| $P_{D1}$[a] | 1 | 1 | 1 | 1 |
| $P_{D2a}$ | | | | |

a = Parameters were equated across all three release groups in last reaches of SD model (affects marked parameters)

b = unique parameters were estimated for different release groups; no pooled estimate is available.

Table E2. (Continued)

| Parameter | 1 | 2 | 3 | Population Estimate (Releases 2 and 3) |
|---|---|---|---|---|
| $P_{D2b}$ | | | | |
| $P_{D2}$ | | | | |
| $P_{E1}$ | | 0 | 0 | |
| $P_{E2}$ | | | | |
| $P_{F1a}$[a] | 1 | 1 | 1 | 1 |
| $P_{F1b}$[a] | 1 | 1 | 1 | 1 |
| $P_{F1}$[a] | 1 | 1 | 1 | 1 |
| $P_{R1a}$ | 1 | 1 | | 1 |
| $P_{R1b}$ | 1 | 1 | | 1 |
| $P_{R1}$ | 1 | 1 | | 1 |
| $P_{G2a}$ | 1 | | | |
| $P_{G2b}$ | 1 | | | |
| $P_{G2}$ | 1 | | | |
| $\lambda$ | 0 | | | |
| $\lambda_{A4}$ | 0 | 0.006 (0.006) | 0 | 0.005 (0.005) |
| $\lambda_{A6}$ | 0 | 0 | 0 | 0 |
| $\lambda_{A7}$ | 0 | 0 | | 0 |
| $\lambda_{B1}$ | 0 | 0.14 (0.13) | 0 | 0.11 (0.10) |
| $\lambda_{B2}$ | 0 | 0.25 (0.22) | | 0.17 (0.15) |
| $\lambda_{R1}$ | 0 | 0 | | 0 |
| $\lambda_{D}$[a] | 1 | 1 | 1 | 1 |
| $\lambda_{E}$[a] | 0.50 (0.25) | 0.50 (0.25) | 0.50 (0.25) | 0.50 (0.25) |

a = Parameters were equated across all three release groups in last reaches of SD model (affects marked parameters)

b = unique parameters were estimated for different release groups; no pooled estimate is available.

**Table E3. Parameter estimates (standard errors in parentheses) from survival model for tagged juvenile Chinook Salmon released in 2014, including predator-type detections. Parameters without standard errors were estimated at fixed values in the model. Population-level estimates are from pooled data from release groups 2 and 3. Some parameters were not estimable because of sparse data. Estimates for release group 1 were not adjusted for premature tag failure.**

| Parameter | 1 | 2 | 3 | Population Estimate (Releases 2 and 3) |
|---|---|---|---|---|
| $S_{A2}$ | 0.82 (0.12) | 0.63 (0.12) | 0.20 (0.03) | 0.34 (0.04) |
| $S_{A3}$ | 0.49 (0.05) | 0.40 (0.06) | 0.37 (0.05) | 0.51 (0.04) |
| $S_{A4}$ | 0.64 (0.03) | 0.49 (0.04) | 0.78 (0.06) | 0.55 (0.03) |
| $S_{A5}$ | 0.25 (0.03) | 0.20 (0.05) | 0.17 (0.07) | 0.19 (0.04) |
| $S_{A6}$ | 0.76 (0.06) | 0.80 (0.10) | | 0.75 (0.10) |
| $S_{A6,G2}$ | 0 | | | |
| $S_{A7}^{a}$ | 0.12 (0.05) | 0.12 (0.05) | 0.12 (0.05) | 0.12 (0.05) |
| $S_{A7,G2}$ | 0 | | | |
| $S_{R1}^{a}$ | 0 | 0 | 0 | 0 |
| $S_{R1,G2}$ | 0 | | | |
| $S_{B1}$ | | | | |
| $S_{B2,G2}$ | 0.11 (0.10) | | | |
| $\phi_{A1,A0}$ | 0 | 0.003 (0.002) | 0.06 (0.01) | 0.03 (<0.01) |
| $\phi_{A1,A2}$ | 1.10 (0.12) | 1.02 (0.12) | 0.89 (0.08) | 0.94 (0.07) |
| $\phi_{B1,B2}$ | 0.53 (0.12) | 0.57 (0.19) | | 0.67 (0.16) |
| $\phi_{B2,B4}$ | | | | |
| $\phi_{B2,C2}$ | | | | |
| $\phi_{B2,D1}^{a}$ | 0.07 (0.05) | 0.07 (0.05) | 0.07 (0.05) | 0.07 (0.05) |
| $\phi_{B2,E1}^{a}$ | 0.27 (0.11) | 0.27 (0.11) | 0.27 (0.11) | 0.27 (0.11) |
| $\phi_{B4,G2}$ | | | | |
| $\phi_{C1,B4}$ | | | | |
| $\phi_{C1,C2}$ | | | | |
| $\phi_{C1,D1}$ | | | | |
| $\phi_{C1,E1}$ | | | | |
| $\phi_{C2,G2}$ | | | | |
| $\phi_{D1,D2}$ | | | | |
| $\phi_{D2,G2}$ | | | | |
| $\phi_{E1,E2}$ | | | | |
| $\phi_{E2,G2}$ | | | | |
| $\psi_{A1}$ | 0.91 (0.02) | 0.91 (0.03) | 0.94 (0.04) | 0.92 (0.02) |
| $\psi_{A2}$ | 0.91 (0.05) | 0.75 (0.12) | | 0.80 (0.10) |
| $\psi_{A3}^{a}$ | 0.60 (0.22) | 0.60 (0.22) | 0.60 (0.22) | 0.60 (0.22) |
| $\psi_{B1}$ | 0.09 (0.02) | 0.08 (0.03) | 0.06 (0.04) | 0.08 (0.02) |
| $\psi_{B2}$ | | | | |
| $\psi_{C2}$ | | | | |
| $\psi_{R2}$ | 0.09 (0.05) | 0.25 (0.13) | | 0.20 (0.10) |
| $\psi_{F3}^{a}$ | 0.40 (0.22) | 0.40 (0.22) | 0.40 (0.22) | 0.40 (0.22) |

a = Parameters were equated across all three release groups in last reaches of SD model (affects marked parameters)

b = unique parameters were estimated for different release groups; no pooled estimate is available.

**Table E3. (Continued)**

| Parameter | 1 | 2 | 3 | Population Estimate (Releases 2 and 3) |
|---|---|---|---|---|
| $P_{A0a}$ | | | 0.96 (0.04) | 0.96 (0.04) |
| $P_{A0b}$ | | | 0.68 (0.08) | 0.65 (0.08) |
| $P_{A0}$ | | | 0.99 (0.01) | 0.99 (0.01) |
| $P_{A2}$ | 0.11 (0.02) | 0.20 (0.03) | 0.49 (0.05) | NA[b] |
| $P_{A3}$ | 0.18 (0.02) | 0.14 (0.03) | 0.78 (0.06) | NA[b] |
| $P_{A4}$ | 0.99 (<0.01) | 1 | 1 | 1 |
| $P_{A5a}$ | | 0.88 (0.04) | 0.93 (0.04) | 0.90 (0.03) |
| $P_{A5b}$ | | 0.90 (0.04) | 1 | 0.93 (0.03) |
| $P_{A5}$ | 1 | 0.99 (0.01) | 1 | 0.99 (<0.01) |
| $P_{A6a}$ | | 1 | 1 | 1 |
| $P_{A6b}$ | | 1 | 1 | 1 |
| $P_{A6}$ | 1 | 1 | 1 | 1 |
| $P_{A7a}$ | 1 | 1 | | 1 |
| $P_{A7b}$ | 1 | 1 | | 1 |
| $P_{A7}$ | 1 | 1 | | 1 |
| $P_{A8a}$[a] | 0.67 (0.27) | 0.67 (0.27) | 0.67 (0.27) | 0.67 (0.27) |
| $P_{A8b}$[a] | 1 | 1 | 1 | 1 |
| $P_{A8}$[a] | 1 | 1 | 1 | 1 |
| $P_{A9a}$ | | | | |
| $P_{A9b}$ | | | | |
| $P_{A9}$ | | | | |
| $P_{B1a}$ | 1 | 1 | 1 | 1 |
| $P_{B1b}$ | 1 | 1 | 1 | 1 |
| $P_{B1}$ | 1 | 1 | 1 | 1 |
| $P_{B2a}$ | 1 | 1 | | 1 |
| $P_{B2b}$ | 1 | 1 | | 1 |
| $P_{B2}$ | 1 | 1 | | 1 |
| $P_{B4a}$ | | | | |
| $P_{B4b}$ | | | | |
| $P_{B4}$ | | | | |
| $P_{C1a}$ | | | | |
| $P_{C1b}$ | | | | |
| $P_{C1}$ | | | | |
| $P_{C2a}$ | | | | |
| $P_{C2b}$ | | | | |
| $P_{C2}$ | | | | |
| $P_{D1}$[a] | 1 | 1 | 1 | 1 |
| $P_{D2a}$ | | | | |

a = Parameters were equated across all three release groups in last reaches of SD model (affects marked parameters)

b = unique parameters were estimated for different release groups; no pooled estimate is available.

**Table E3. (Continued)**

| Parameter | 1 | 2 | 3 | Population Estimate (Releases 2 and 3) |
|---|---|---|---|---|
| $P_{D2b}$ | | | | |
| $P_{D2}$ | | | | |
| $P_{E1}$ | 1 | 1 | 1 | 1 |
| $P_{E2}$ | | | | |
| $P_{F1a}$[a] | 1 | 1 | 1 | 1 |
| $P_{F1b}$[a] | 1 | 1 | 1 | 1 |
| $P_{F1}$[a] | 1 | 1 | 1 | 1 |
| $P_{R1a}$ | 1 | 1 | | 1 |
| $P_{R1b}$ | 0.67 (0.27) | 1 | | 1 |
| $P_{R1}$ | 1 | 1 | | 1 |
| $P_{G2a}$ | 1 | | | |
| $P_{G2b}$ | 1 | | | |
| $P_{G2}$ | 1 | | | |
| $\lambda$ | 1 | | | |
| $\lambda_{A4}$ | 0.004 (0.003) | 0.006 (0.006) | 0 | 0.005 (0.005) |
| $\lambda_{A6}$ | 0 | 0 | 0 | 0 |
| $\lambda_{A7}$ | 0 | 0 | | 0 |
| $\lambda_{B1}$ | 0.06 (0.06) | 0.14 (0.13) | 0 | 0.11 (0.10) |
| $\lambda_{B2}$ | 0.11 (0.10) | 0.25 (0.22) | | 0.17 (0.15) |
| $\lambda_{R1}$ | 0 | 0 | | 0 |
| $\lambda_{D}$[a] | 1 | 1 | 1 | 1 |
| $\lambda_{E}$[a] | 1 | 1 | 1 | 1 |

a = Parameters were equated across all three release groups in last reaches of SD model (affects marked parameters)

b = unique parameters were estimated for different release groups; no pooled estimate is available.